Chapter 5

MARINE BIRD ABUNDANCE AND HABITAT USE

by

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SUMMARY

Seasonal shipboard surveys were conducted to assess abundance and distribution patterns of marine birds in the Unimak Pass area. These patterns were related to marine habitat (water masses) as determined by ancillary environmental sampling. Specimens were collected for dietary analysis. A summary of pertinent findings includes the following:

(1) Overall density of marine birds in this area was highest in winter (425 birds/km^2), intermediate in fall (281 birds/km^2), and lowest in spring (80 birds/km^2).

(2) Fall populations were strongly dominated by Short-tailed Shearwaters, and winter populations by Crested Auklets; during spring, dominance by any single species was less evident than during the previous seasons.

(3) During fall, Short-tailed Shearwaters exhibited the highest densities in Shelf Break Water near the shelf break in the Bering Sea but were also abundant in the Gulf of Alaska Water mass, north of the island chain. These areas of abundance correspond to the north ends of the two major passes in the study area—Unimak and Akutan.

(4) In winter, the Crested Auklet exhibited highest densities in the Alaska Coastal Water mass, north of Unimak Island. An additional major concentration area was located in Akutan Pass.

(5) In spring, abundance of birds was more equitable among water masses than was observed during other seasons, but bird densities were low overall.

(6) A main finding of the dietary analyses was the importance of *Thysanoessa* euphausiids to marine birds, including Short-tailed Shearwaters and Whiskered Auklets during the fall, Whiskered Auklets and Common Murres in winter, and Whiskered Auklets in spring. This study contributed substantially to the known food habits of Whiskered Auklets.

(7) Of the five species subjected to dietary analyses, only Tufted Puffins did not use euphausiids to a significant degree. The puffins collected had fed largely upon *Gonatus* squid in fall and *Ammodytes* fish during spring. Near the breeding islands they were known to prey primarily on juvenile pollock.

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INTRODUCTION

Unimak Pass is one of the major migration corridors for bird populations entering and leaving the Bering Sea (Strauch and Hunt 1982, Thorsteinson 1984). The abundance of birds in the Unimak area is so large and regionally important that potential impacts in this area (resulting from increased vessel traffic) are listed as being of concern even for developments spatially removed, such as the Navarin Basin. An estimate of 1.1 million shearwaters in the pass has been made in the fall (see Armstrong et al. 1984). The mean density of all species using the pass in summer was estimated by Strauch and Hunt (1982) to be 224 birds/km^2 or 720,000 birds in the pass area. Hunt et al. (1982) identified the Unimak Pass area as one of the regions in the southeastern Bering Sea with consistently highest densities of seabirds and thus potentially of great sensitivity with respect to oil spills.

The purpose of this study was to conduct systematic shipboard surveys to determine marine bird use of the Unimak Pass area. While the study largely constituted a descriptive effort, the objectives were to relate temporal and spatial habitat use patterns of marine birds to water masses and available prey densities. In this chapter we present a synthesis of available information pertaining to key species and species groups of marine birds, descriptors of habitats used by these organisms in time and space, and food habits information.

CURRENT STATE OF KNOWLEDGE

General

Regional summaries of seabirds in or near the area of interest have been compiled for the Unimak Pass area (LGL 1986), North Aleutián Shelf (Armstrong et al. 1984), and St. George Basin (Strauch and Hunt 1982). The most comprehensive study of breeding seabirds in the area is that of Nysewander et al. (1982). Summaries of the status of breeding colonies were obtained from the USFWS seabird colony database (provided by Art Sowls). Similarly, updated pelagic seabird summaries were obtained from the pelagic seabird database (provided by D. Forsell, USFWS). Additional unpublished data were obtained from the North Aleutian Shelf (NAS) Ecological Process Study (Troy and Johnson 1987). Much of the life history information for seabirds in the Bering Sea (presented below) was summarized from Lewbel (1983). The available literature emphasizes insular areas and the Bering Sea portion of the study area. Relatively little information exists for the Gulf of Alaska south of the Krenitzin Islands.

The Unimak Pass area has been envisioned by some as filling an important trophic role for birds in the Bering Sea ecosystem. Although only about 0.03% of the midshelf primary productivity is funnelled into birds

(Schneider and Hunt 1982), their consumption of particular resources (e.g., walleye pollock) may be substantial. Armstrong et al. (1984) reasoned that the impact of birds on pelagic prey resources was probably greatest at a few specific areas, one being Unimak Pass.

Two species of endangered birds—Aleutian Canada Goose and Short-tailed Albatross—have been found within the Unimak Pass/eastern Aleutian Islands area. The Short-tailed Albatross occurred regularly in this area before its population was reduced to the brink of extinction. Bones of this species are found in archaeological diggings in our study area (e.g. Rauzon 1976, Yesner and Aigner 1976). A juvenile Short-tailed Albatross was reported NW of Akutan Island (at 54°29'N, 166°13'W) as recently as August 1985 (see Gibson 1985). Neither species is known to breed in the study area (it is quite distant from the historical breeding distribution of Short-tailed Albatross) nor does the study area contain areas of regular use. Aleutian Canada Geese have been encountered during the breeding season on Aiktak Island in 1981 and 1982, but evidence of nesting has not been found (Forsell 1983a,b). An estimated 50 pairs of Aleutian Canada Geese nest on Chagulak Island just west of our area of interest (Bailey and Trapp 1984), and another small isolated population occurs on Kaliktagik Island east of Unimak Pass (Hatch and Hatch 1983).

High densities of seabirds, generally resulting from large aggregations, are frequently found in and near Unimak Pass. Surveys show that Glaucous-winged Gulls, auklets (primarily Crested Auklets), shearwaters (primarily Short-tailed Shearwaters), Common Murres, and Black-legged Kittiwakes are the most numerous species (Table 1).

Abundance varies markedly with season (Tables 1 and 2). For example, kittiwakes and shearwaters peak during summer; Crested Auklets and murres peak during winter. Birds relatively numerous through most of the year are Glaucous-winged Gull, Northern Fulmar, Black-legged Kittiwake, cormorants (Red-faced), and auklets.

Shipboard transect results, as contained in the USFWS pelagic database (Table 2), show some important characteristics of the eastern Aleutian area by virtue of including transects between islands and within some smaller passes. Of particular interest is the high densities of small alcids, particularly Whiskered Auklets. These transects were censused opportunistically, often while observers ferried between specific areas, and do not permit a rigorous comparison for either temporal or spatial trends.

Approximately 1.1 million seabirds attend nesting colonies in the Fox Islands (Table 3). The predominant nesting species are Tufted Puffin, Fork-tailed Storm-Petrel, and Leach's Storm-Petrel. This total includes about 50% of the Alaska population of Whiskered Auklet (*Aethia pygmaea*) and about 45% of the Alaska population of Tufted Puffin (*Fratercula cirrhata*). The composition of the breeding seabird community in this area differs markedly

Table 1. Densities of marine birds (#/km^2) in Unimak Pass area, Alaska (Cape Mordvinof to Akun Island) recorded during North Aleutian Shelf aerial surveys (data from work of Troy and Johnson 1987).

SPECIES	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Red-throated Loon	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Pacific Loon	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Common Loon	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
loon	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
grebe	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Northern Fulmar	0.9	2.2	1.3	0.3		0.2		2.0		5.2	0.0	0.1
shearwater-dark	0.0	0.0	0.0	0.0		64.5		46.5		0.2	0.0	0.0
Fork-tailed Storm-Petrel	0.0	0.0	0.0	0.0		1.5		0.5		0.2	0.0	0.0
cormorant	3.2	0.3	0.0	0.2		1.0		2.4		1.5	3.5	0.3
Emperor Goose	0.0	0.0	0.0	0.3		0.0		0.0		0.0	0.0	0.0
Brant	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Mallard	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Common Eider	0.5	0.2	0.0	0.0		0.0		0.0		0.0	0.0	0.0
King Eider	0.7	3.8	0.2	0.7		0.0		0.0		0.0	0.0	1.2
Steller's Eider	0.1	1.1	0.1	0.0		0.0		0.0		0.1	0.0	0.9
Harlequin Duck	0.0	0.0	0.0	0.1		0.0		0.0		0.0	0.3	0.0
Oldsquaw	0.0	2.3	0.6	0.4		0.0		0.0		0.0	0.0	0.4
scoter	2.7	1.0	1.8	1.0		0.0		0.0		0.0	0.1	0.3
Red-breasted Merganser	0.0	0.0	0.0	0.0		0.3		0.0		0.0	0.0	0.0
duck	0.0	0.0	0.3	0.0		0.2		0.0		0.0	0.0	0.0
Bald Eagle	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Rock Sandpiper	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
small sandpiper	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
phalarope	0.0	0.0	0.0	0.0		0.0		0.9		1.0	0.0	0.0
shorebird	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
jaeger	0.0	0.0	0.0	0.0		0.0		0.1		0.0	0.0	0.0
Bonaparte's Gull	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Mew Gull	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Herring Gull	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Glaucous-winged Gull	5.5	31.6	18.2	19.8		2.0		75.9		13.8	131.6	3.7
Glaucous Gull	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Black-legged Kittiwake	0.0	0.1	0.4	3.2		5.7		11.7		5.0	0.1	0.1
Sabine's Gull	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
tern	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Murre	0.6	67.3	1.0	14.8		0.1		0.2		0.1	0.1	0.1
Pigeon Guillemot	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
murrelet	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
auklet	71.3	0.0	8.1	80.7		0.2		0.2		0.1	2.8	9.0
Tufted Puffin	0.0	0.0	0.0	0.0		0.6		4.2		0.0	0.0	0.0
Horned Puffin	0.0	0.0	0.0	0.1		0.0		0.0		0.0	0.0	0.0
alcid	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Common Raven	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
Snow Bunting	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
passerine	0.0	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0
TOTAL	85.7	110.0	32.2	121.6		76.3		144.6		27.2	138.7	16.2

Table 2. Densities of marine birds (#/km2) in the Unimak-Krenitzin Islands area, Alaska (FWS seabird colony database).

SPECIES	April-May	June-Aug	Sept-Oct	Nov-March
loons				0.05
Black-footed Albatross			0.06	
Northern Fulmar	0.56	4.91	15.43	1.16
total shearwaters	0.19	829.08	418.76	0.38
Fork-tailed Storm-Petrel		1.62	0.77	0.12
total cormorants	1.51	0.77	0.21	1.48
duck-goose	0.01			0.03
Oldsquaw	2.99			0.03
Harlequin Duck				0.13
Black Scoter				0.05
White-winged Scoter			0.01	
eider	0.36			
total phalaropes	2.43	4.39	0.56	0.00
total jaegers		0.18	0.01	
gull		0.08		0.03
Glaucous Gull		0.01		
Glaucous-winged Gull	0.94	1.24	3.47	5.70
Thayer's Gull		0.00		
kittiwake		0.47	0.78	4.64
Black-legged Kittiwake	0.49	0.52	2.24	0.45
Red-legged Kittiwake		0.01	0.03	
Arctic Tern		0.00	0.07	
alcid	1.87	1.35	2.07	3.85
small alcid	0.16	2.32		
small dark alcid	0.12			
total murres	18.60		2.92	11.74
Pigeon Guillemot	0.22	0.10		
Ancient Murrelet	1.36	1.17	0.33	
Cassin's Auklet	0.21	0.06	0.06	
Parakeet Auklet	0.02	0.00	0.31	0.16
auklet	0.60			
Crested Auklet	0.18	0.02	0.58	30.63
Least Auklet	2.60	0.49		0.18
Whiskered Auklet	11.31	3.27	0.01	
Horned Puffin	0.10	0.48	0.65	0.47
Tufted Puffin	25.64	25.28	4.09	0.42
TOTAL	72.47	877.82	453.42	61.70
Number of Transects	67	103	39	24
Area Sampled (sq. km)	82.3	126.4	220.5	37.9

Table 3. Seabird colonies of the eastern Aleutian Islands and Unimak Pass area, Alaska. Values listed are the most representative estimates in the FWS Alaska seabird colony database (ID numbers given in column headings). Asterisks denote possible nesting but population size unknown.

SPECIES	23-002 Unalga Island	23-004 South Amaknak Island	23-005 Egg Island	23-015 Triangle Ear	23-018 West Hive Bay	23-019 East Hive Bay	23-020 South-west Udagah	23-043 Eider Point
Fork-tailed Storm-Petrel	*		200000					
Leach's Storm-Petrel	*		70000					
Cormorant	52							
Double-cr Cormorant	250		82	6				
Pelagic Cormorant				2		8	*	
Red-faced Cormorant	144		488			6	18	30
Common Eider	50							
Black Oystercatcher			14					
Glaucous-winged Gull			1346	140				
Pigeon Guillemot	135	*	350				*	
Ancient Murrelet			5000					
Cassin's Auklet			2000					
Whiskered Auklet			10					
Horned Puffin	189	20	*	65				
Tufted Puffin	35		163316		130		270	
TOTAL	855	20	442606	213	130	14	288	30

SPECIES	23-045 Hog Island	23-046 Tanaskan Bay Island	23-047 Dushkot Island	23-048 Round Island	23-049 Islet at North Sedanka Island	23-050 Old Man Rock	23-051 Cape Morgan	23-052 Reef Point
Double-cr. Cormorant					72		46	8
Pelagic Cormorant					6			
Red-faced Cormorant					*	2	784	1036
Black Oystercatcher		21	7	4				
Glaucous-winged Gull	200	180	800					4
Black-legged Kittiwake			32					
Pigeon Guillemot	142	198	96	86			20	34
Horned Puffin	54						4	6
Tufted Puffin		3106	3645	11504	130		1000	
TOTAL	396	3505	4580	11594	208	2	1854	1088

Table 3 (cont.)

SPECIES	23-053 Lava Point	23-054 Kiliuik Bay & Nest Rock	23-055 Kisselen Bay	23-056 Eriskine Bay	23-057 McIver Bight Island	23-058 Mist Triangle	23-059 Auket Island
Fork-tailed Storm-Petrel							200
Leach's Storm-Petrel							300
Pelagic Cormorant						42	
Red-faced Cormorant	1408						
Black Oystercatcher		7	17	5			6
Glaucous-winged Gull	6	32	150	16			
Black-legged Kittiwake			28				
Pigeon Guillemot		4		42			30
Ancient Murrelet							200
Cassin's Auklet							3500
Horned Puffin	32			36			*
Tufted Puffin			112	100	40		41696
TOTAL	1446	43	307	199	40	42	45932

SPECIES	23-060 Tangagm Island	23-061 Excelsior Island	23-062 Adokt Island	23-063 Koschekt Island	24-001 Rootok Island	24-003 Mt. Gilbert Akun Island	24-004 2.5 mi North Sennet Point	24-005 Scotch Cap Rock
Fork-tailed Storm-Petrel	1500	2000	1000	2500	*			
Leach's Storm-Petrel	1500	2500	1000	2500	*			
Double-cr. Cormorant					20	6		
Red-faced Cormorant	*	98	142		68	150	30	200
Black Oystercatcher	16	12	28	26		2		
Glaucous-winged Gull		30	60	130	20	200		
Common Murre		12						
Pigeon Guillemot	150	115	70	34	8			
Ancient Murrelet	600	400	700	300				
Cassin's Auklet		2000	40					
Whiskered Auklet	2	4	*	2				
Horned Puffin			40	*	74			
Tufted Puffin	27331	40201	25492	10998				
TOTAL	31099	47372	28572	16490	190	358	30	200

Table 3 (cont.)

SPECIES	24-006 Sealion Point	24-007 Cave Point	24-008 Cape Mordvinof	24-009 Derbin Island	24-010 Tigalda Island	24-011 Ugamak Island	24-012 Kaligagan Island	24-013 Cape Luke
Fork-tailed Storm-Petrel				600	*		7500	
Leach's Storm-Petrel				800	*		5500	
Cormorant			*					
Double-cr. Cormorant	*			108				
Pelagic Cormorant	50							
Red-faced Cormorant	560	1000	*		164		280	60
Common Eider					10			
Black Oystercatcher				12	*	4		
Glaucous-winged Gull				1318	100		2000	
Black-legged Kittiwake			*					
Aleutian Tern			*					
Common Murre				23			300	
Pigeon Guillemot				34	270	142	328	
Ancient Murrelet				100			1000	
Cassin's Auklet							50	
Whiskered Auklet				4	*		18	
Horned Puffin			*	6	304	268	20	*
Tufted Puffin	30		*	9485	*	130	111082	*
TOTAL	640	1000	0	12490	848	544	128078	60

SPECIES	24-014 Slice Island	24-015 Derbin Strait Islets	24-016 Tanginak Island	24-017 Tangik Island	24-018 Puffin Island	24-019 Poa Island	24-020 Jackass Point	24-021 South Island, Akun Strait
Fork-tailed Storm-Petrel	*		*	4500	800	5000	*	
Leach's Storm-Petrel	*		*	300	100	700	*	
Double-cr. Cormorant			8				214	
Pelagic Cormorant			245					
Red-faced Cormorant			455	38			98	
Black Oystercatcher				16	6	15	*	
Glaucous-winged Gull			182	350		1060	163	
Black-legged Kittiwake			346					
Common Murre			880					
Thick-billed Murre			220					
Pigeon Guillemot		122	12	18	45	15		
Ancient Murrelet				350	200	1000		
Whiskered Auklet	*		*	10	10	25		4
Horned Puffin	*		4					
Tufted Puffin	260	130		20228	35374	33484	340	
TOTAL	260	252	2352	25810	36535	41299	815	4

Table 3 (cont.)

SPECIES	24-022 North Island, Akun Strait	24-023 Surf Bay Islets	24-024 Akun Head	24-025 Pinnacle by Little Bay	24-026 Kaligagan Islets #2	24-027 Kaligagan Islets #3	24-028 Kaligagan Islets #6
Fork-tailed Storm-Petrel	200				600		*
Leach's Storm-Petrel	*				300		*
Double-cr. Cormorant			24				
Red-faced Cormorant	10	4	210	12			8
Common Eider		*					
Black Oystercatcher	10	2			14	1	
Glaucous-winged Gull		90	15	27	44	54	167
Aleutian Tern		*					
Pigeon Guillemot	162	4			30	40	
Ancient Murrelet	400				500		*
Cassin's Auklet	*				300		*
Parakeet Auklet	*						
Whiskered Auklet	4	*			10		*
Horned Puffin	8	*					2
Tufted Puffin	53372		306	196	15198		668
TOTAL	54166	100	555	235	16996	95	845

SPECIES	24-029 Kaligagan Islets #4	24-030 Kaligagan Islets #1	24-031 Kaligagan Islets #5	24-032 Aiktak Island	24-033 Round Island	24-034 Don Pinnacle Ugamak	24-035 Battery Point
Fork-tailed Storm-Petrel		36		15000	*	*	
Leach's Storm-Petrel		40		8500		*	
Double-cr. Cormorant				84			30
Pelagic Cormorant				62			
Red-faced Cormorant			28	1588			192
Common Eider							*
Black Oystercatcher	2	8		49			
Glaucous-winged Gull	30		60	2750	126		60
Common Murre			55	12600			22
Thick-billed Murre				2400			
Pigeon Guillemot	50	132	12	68			*
Ancient Murrelet		*		1000			
Cassin's Auklet		100		*			
Whiskered Auklet		8		6	*	*	
Horned Puffin				32			130
Tufted Puffin		5508	260	102428	262	1000	
TOTAL	82	5832	415	146567	388	1000	434

Table 3 (cont.)

SPECIES	24-036 Talus Point	24-037 Akutan Harbor Islets	24-038 Akutan Point	24-039 North Head	24-040 Pt 2 km east of Light	24-041 Light	TOTAL
Fork-tailed Storm-Petrel							**241436**
Leach's Storm-Petrel							**94040**
Cormorant					*	*	**52**
Double-cr. Cormorant			4				**962**
Pelagic Cormorant			4				**419**
Red-faced Cormorant	108		636	90			**10145**
Common Eider							**60**
Black Oystercatcher	*						**304**
Glaucous-winged Gull		44					**11954**
Black-legged Kittiwake							**406**
Aleutian Tern							**0**
Common Murre							**13892**
Thick-billed Murre							**2620**
Pigeon Guillemot	*	58					**3056**
Ancient Murrelet							**11750**
Cassin's Auklet							**7990**
Parakeet Auklet							**0**
Whiskered Auklet			2				**119**
Horned Puffin	65	24	66				**1449**
Tufted Puffin		40	2500				**721387**
TOTAL	173	166	3212	90	0	0	**1122041**

from that of many areas in Alaska, particularly elsewhere in the Bering Sea, in that murres and kittiwakes are a minor component. Rather, burrowing seabirds and notably nocturnal species (storm-petrels, Ancient Murrelet, Cassin's Auklet) are numerically dominant.

Detailed work on the breeding biology of birds in this area is lacking; however, seabirds are probably present on the colonies from at least April through November. Egg laying probably commences during May and hatching in late June. Fledging of Leach's Storm-Petrels (*Oceanodroma leucorhoa*) and Tufted Puffin may occur as late as October or November. Many aspects of the seabird colonies in this area are more fully discussed in Chapter 8 (SEABIRD COLONIES) of this volume.

The waters around the eastern Aleutians are especially important to nesting birds. In this area seabirds have short flying times to a variety of marine environments, including a broad continental shelf, a precipitous shelf break, and deep oceanic expanses. In addition, the eastern Aleutians have many deep and protected bays and inlets, and a tidal flow which creates rip tides within the straits and passes.

Key Species and Groups

In this section we summarize some of the available survey information for key study species. As in most survey programs such as this all species encountered were recorded. Nonetheless, it was important to identify the key species so that the study design could be optimized for them. The spatial distribution of sampling effort in an area as diverse as our study region can greatly influence resultant abundance indices and their comparability with neighboring and future efforts. To select key study species required a close examination of the existing data in the context of study objectives.

Examination of Tables 1 and 2 reveals that meaningful attempts to rank species in importance (using abundance as a measure of importance) is not an easy task. Differing lists can be derived based on survey type (ship vs. aerial), season, or abundance criteria (maximum vs. average). Based on the aerial surveys and using maximum abundance as the selecting criterion the five key species groups would be Glaucous-winged Gull, auklets (Crested), shearwaters (Short-tailed), murres (Common), and Black-legged Kittiwake. If persistence is incorporated as a selection criterion this list is changed to Glaucous-winged Gull, Northern Fulmar, Black-legged Kittiwake, cormorants (Red-faced), and auklets (Crested). The differences between these lists reflects the changing composition of the region's avifauna. Species such as the shearwaters and murres reach very high densities but only for short portions of the year (shearwaters in summer, murres in winter). Inclusion of Northern Fulmar and cormorants in the second list reflects their year-round residence in the study area at, on average, moderate levels of abundance.

The shipboard surveys indicate a somewhat different list of key species. Based on maximum densities, the five most numerous species are shearwaters, Tufted Puffin, murres, Northern Fulmar, and Crested Auklet. Only maximum density was used in this selection as ship surveys did not have the same temporal coverage in the study area as aerial surveys. Differences in shipboard vs aerial studies probably reflect a combination of disparities in spatial and temporal coverage. Shipboard work emphasizes the spring/summer period when species such as shearwaters dominate the avifauna. Coverage by the shipboard work also ranged further west than the aerial surveys, thus sampling a somewhat different region. Finally, the aerial surveys permit sampling closer to shore, accounting for the higher abundance of coastal species such as gulls and cormorants than have been observed in the farther-offshore shipboard surveys.

Agency objectives and scientists' opinions strongly influenced key species selection. The solicitation for this study listed alcids and seaducks as groups on which to focus. The discussion above listed several alcids occurring in abundance in the study area, but no seaducks. Seaducks are shown in Table 1 to be an important component of the winter avifauna; as a group, they tend to remain in coastal areas and are only infrequently encountered in high numbers during shipboard surveys (e.g., Table 2). Focal species identified at the MMS-sponsored conference on Monitoring Seabird Populations (November 1984) were murres, Tufted Puffins, Whiskered Auklets, and seaducks; the table summary also listed Glaucous-winged Gull. This source adds Whiskered Auklets to the list of birds already under consideration. Whiskered Auklets reached appreciable densities on some cruises (Table 2) in the area, but available data did not indicate that this species was a dominant component of the avifauna. This species is of interest because of its restricted distribution (more or less endemic to the Aleutians) and relative abundance in our study area.

The Short-tailed Albatross, an endangered species, has been recorded within our study area. Findings of bones by archaeologists in middens indicate that this species was relatively numerous in the area in the past. Sightings of this species away from its breeding island are quite rare but some have been made within our study area, but the probability of encounter is so slight that study designs should not be altered to learn more about this species.

Combining all these measures of importance is a subjective endeavor. In doing so, we have given greatest weight to the objectives identified in the solicitation for this study, followed by the suggestions of the monitoring conference, and finally to abundance based on existing survey data. The target groups resulting from this subjective process are:

- seaducks
- Whiskered Auklet
- Crested Auklet
- shearwaters
- murres
- Tufted Puffin
- Glaucous-winged Gull

Below are brief accounts of the life histories of these species or groups as well as some additional species that figure prominently in the study results.

Northern Fulmar (*Fulmarus glacialis*).

The Northern Fulmar occurs year-round in the Unimak Pass area. The eastern Bering Sea population is estimated to be near one million and is concentrated at a few breeding locations (Sowls et al. 1978). All but a few thousand breed in three areas: Chagulak Island in the Aleutians, the Pribilof Islands, and St. Matthew/Hall islands. No fulmars are known to nest in the Krenitzin Islands.

During the summer fulmars at sea are concentrated along the shelfbreak and outer shelf near the Pribilof Islands and south to Unimak Pass, often in close association with fishing fleets. They are markedly less common in the shallow waters of Bristol Bay and the inner shelf (Hunt et al. 1981c). In winter, most fulmars leave the Bering Sea for the north Pacific; however, some are still present in ice-free waters north and west of the Pribilof Islands and towards Unimak Pass. Birds from many areas, particularly northern colonies, use the pass as a migration corridor. Fulmar numbers are generally lower in the pass area than in the shelfbreak waters to the northwest and southeast. Murie (1959) suggested that fulmars in the Aleutian Islands are most abundant in rip tide areas and offshore of their breeding colonies. Cahn (1947) also mentioned congregations of fulmars within the passes of the eastern Aleutians, especially during late summer and winter. Densities may reach up to 17 birds/km^2 in Unimak Pass in the fall (Gould 1982)

Fulmars feed by surface-seizing (Ashmole 1971). They prey on cephalopods, crustaceans and fish. Fulmars have become habituated to scavenging fish offal from fishing vessels as a major food source (Hunt et al. 1981c).

Short-tailed (*Puffinus tenuirostris*) and Sooty Shearwaters (*P. griseus*).

Both of these species occur in the study area. Unfortunately, they cannot be consistently differentiated during pelagic surveys and many identifications are suspect. Because of this, specific areas of abundance for each

species are difficult to delimit. In general it appears that Sooty Shearwaters are most abundant in the Gulf of Alaska whereas most Short-tailed Shearwaters occur within the Bering Sea. There is a zone of overlap in the southern Bering Sea and both species occur in our area of interest. Reported densities and distributions of shearwaters in the Bering Sea, in which species are not named, usually reflect movements of Short-tailed Shearwaters because this species probably accounts for >90% of all shearwaters in that area (e.g., Troy and Johnson 1987).

Unlike other key species, these shearwaters nest in the southern hemisphere and migrate to the North Pacific for the northern summer (their nonbreeding season). From May through September the Short-tailed Shearwater is the most abundant species in the Bering Sea. They are typically found over the continental shelf, with only moderate numbers occurring over the shelf break. In the Bering Sea they are frequently concentrated near and within the 50-m isobath. Flocks of at least 100,000 are common, and flocks of over 1,000,000 have been reported. Concentrations of over 1,000,000 shearwaters have been recorded feeding in Unimak Pass in July and movements in excess of 25,000 birds/hour over several hours have been recorded during April and May (FWS, unpubl. data).

Although frequent mention is made of large numbers of shearwaters in association with Unimak Pass, other passes in the area are also used and/or transited by these species. Guzman (1981) mentions major concentrations at Akutan Pass and Trapp (1975) describes movements in Baby Pass.

Shearwaters feed mainly by pursuit diving but also exhibit surface seizing feeding behavior (Hunt et al. 1981a). They probably feed entirely within the upper 5 m of the water column. In the North Aleutian Shelf study area (slightly overlapping the east portion of the present study area), Short-tailed Shearwaters were found to prey largely on euphausiids and sand lance with the proportions varying seasonally (Troy and Johnson 1987).

Fork-tailed Storm-Petrel (*Oceanodroma furcata*).

Both the Fork-tailed Storm-Petrel and the Leach's Storm-Petrel (*O. leucorhoa*) nest in the Aleutians in large numbers (Sowls et al. 1978). Leach's Storm-Petrels are rarely seen in the Bering Sea except at the breeding colonies; they apparently forage to the south of the Aleutian chain in deep oceanic waters of the North Pacific (Hunt et al. 1981c).

Fork-tailed Storm-Petrels are restricted to the Pacific Ocean. They breed from the Kurile Islands through the Aleutians, along the southern and southeastern coasts of Alaska, and south to northern California (Sowls et al. 1978). Nesting populations in the Aleutians may be on the order of three million birds, based on the estimate by Sowls et al. (1978). However, the currently documented breeding population is only 875,000.

Fork-tailed Storm-Petrels are quite commonly sighted in Bering Sea waters. Aerial and shipboard surveys by Hunt et al. (1981c) and Gould et al. (1982) suggest a summer population on the order of three to six million storm-petrels feeding in the eastern Bering Sea. The pelagic distribution of Fork-tailed Storm-Petrels during the summer is as follows: storm-petrels are rarely found north of 58 degrees (Hunt et al. 1981c) and are most numerous at the shelfbreak and on the outer shelf (Hunt et al. 1982). Although absolute densities over deep oceanic waters are lower than at the outer shelf and the shelf break, Fork-tailed Storm-Petrels are among the most numerous birds in deep water areas. In a winter survey in the southeastern Bering Sea, Fork-tailed Storm-Petrels were seen only over deep waters (Hunt et al. 1981c).

Fork-tailed Storm-Petrels feed by surface-seizing or pattering on the surface (Hunt et al. 1981c) and probably feed at night, at least during the breeding season (Quinlan 1979). Food habits are poorly known, but squid, fish, euphausiids and fish offal are eaten by adults (Day 1980, Hunt et al. 1981a). Invertebrates brought to chicks by adult storm-petrels at Wooded Islands included calanoid copepods, euphausiids, gammarid amphipods, cephalopods, and shrimp (Quinlan 1979). Fish found in these food loads included cottids, gadids, myctophids and scorpiniformes (Quinlan 1979).

Red-faced Cormorant (*Phalacrocorax urile*).

Red-faced, Pelagic (*P. pelagicus*), and Double-crested cormorants (*P. auritus*) all occur in the area of interest, but the Red-faced Cormorant predominates. Nelson (1976) estimated the three species occurred in a 6:2:1 ratio at Unimak Island during the fall but their abundance as breeding birds in the area of interest is roughly 20:1:2 (Table 3). Red-faced Cormorants nest on cliffs; in the Pribilofs they are restricted to portions of cliffs less than 200' (Hickey 1976, Troy and Baker 1985). Nests are constructed at least partially of seaweed.

Red-faced Cormorants are probably year-round residents through most of their range, although some movement is evident in the Aleutian Islands because their population levels are lower in the winter than during the breeding season (Byrd et al. 1980). A southward movement of cormorants, predominantly Red-faced, was recorded through Unimak Pass from 7 April to 26 May 1976 (Nelson and Taber, FWS, unpubl. data). Gill et al. (1979) thought it unlikely that this was the result of cormorants wintering in the Bering Sea, but other surveys (LGL 1986) suggest that cormorant densities in northern Unimak Pass peak during winter (Table 1).

Cormorants feed near shore and are seldom seen more than a few km from their breeding colonies during the nesting season. A few are seen in small numbers in the open ocean during spring and fall (Hunt et al. 1981c, LGL 1986). Their feeding method is pursuit-diving (Ashmole 1971). Fish are

the primary prey, but decapods (shrimp and crab) and amphipods are also eaten. Sculpins were the most frequently taken fish. Cormorants appear to be restricted to foraging close to land near the bottom (Hunt et al. 1981a).

Seaducks.

Surprisingly little information is available on seaduck use of the study area. The most detailed survey available is that of Arneson (1980), but that study consisted of a single winter aerial survey. Nonetheless, his study, other opportunistic observations, and findings in the adjacent North Aleutian Shelf (LGL 1986) all point to a high potential for use of the study area by wintering waterfowl. Use of the area by molting seaducks (as occurs in the NAS) has not been investigated.

During a winter survey of coastal areas in the Fox Islands, Arneson (1980) found a mean density of 94 birds/km^2, mostly waterfowl and shorebirds. The highest density (3240 birds/km^2), mostly waterfowl, was found around Samalga Island to the west of our area of interest. At this latter location sea ducks accounted for 416 birds/km^2 of the total density.

Unimak Pass has been shown to be an important migration corridor for waterfowl by Gill et al. (1979). Steller's Eiders (*Polysticta stelleri*) winter primarily along the south side of the Alaska Peninsula from Unimak Pass to Kodiak Island. Common Eiders (*Somateria mollissima*) migrate in large numbers from the Gulf of Alaska into the Bering Sea but there are few records from Unimak Pass. Presumably most of these birds pass directly over the Alaska Peninsula (Gill et al. 1979). Although never reaching the high densities characteristic of other seaducks within our study area, Common Eiders are probably the predominant nesting duck as most of the others occur primarily as winter residents.

Most of the western Canadian, an unknown portion of the Siberian, and all of the Alaskan breeding populations of King Eiders (*Somateria spectabilis*), are thought to winter in the southern Bering Sea and Bristol Bay (Bellrose 1976). In the major wintering area, birds tend to congregate in the eastern Aleutians and off the major lagoons along the western Alaska Peninsula. During normal ice years, birds usually do not begin to increase along the Alaska Peninsula until after November. They are not reported to arrive in the eastern Aleutians until early December (Cahn 1947).

Concentrations of wintering Black Scoters occur in Prince William Sound, around Kodiak Island, along the Alaska Peninsula, and throughout the Aleutian Islands (Bellrose 1976).

Seaducks as a group feed on benthic invertebrates. There is considerable specialization among species, but the groups expected to

predominate in the study area, scoters and King Eiders, feed primarily on bivalve molluscs.

Glaucous-winged Gull (*Larus glaucescens*).

Glaucous-winged Gulls are in many respects an overlooked seabird. Most regional species accounts tend to omit this species. The summaries in Tables 1 and 2 show this species to be consistently among the most numerous species encountered. Its abundance varies seasonally with peak densities occurring in summer and fall, at least in coastal areas.

Glaucous-winged Gulls are omnivorous and are opportunistic foragers. Their diet includes a variety of intertidal organisms, fish, garbage, offal, and other prey. Most foraging occurs in nearshore habitats, especially during the breeding season, but some gulls may be found quite far offshore. Because of their opportunistic foraging behavior, the diet of Glaucous-winged Gulls is prone to great geographic variability.

Black-legged Kittiwake (*Rissa tridactyla*).

Black-legged Kittiwakes are circumpolar in distribution and are numerous in the eastern Bering Sea, with the breeding population estimated at a minimum of 750,000 (Sowls et al. 1978). Population indices derived from aerial and shipboard censuses indicate the presence of 1-3 million kittiwakes in summer and 3-4.5 million in fall over the eastern Bering Sea (Gould et al. 1982).

Nesting colonies of Black-legged Kittiwakes occur throughout the Aleutian Islands, the Bering Sea, and the Gulf of Alaska; however, there are no major nesting areas within the study area. The pelagic distribution during all seasons may be characterized as low density and dispersed in the southern sector of the Bering Sea. Hunt et al. (1982) described a tendency for higher densities to be observed between the 100 m isobath and deeper waters of the shelfbreak, and for lower densities to occur between the 50- and 100-m isobaths.

In winter, most Black-legged Kittiwakes leave the Bering Sea, although this species still occurs in low densities during the winter north of the Aleutians, on the shelfbreak, and in oceanic waters north of the Pribilofs. Kenyon (1949) reported few in the Gulf of Alaska and northeastern Pacific; however, kittiwakes are more common along the California coast and over a broad zone of deep oceanic water south of the Aleutians. Gould et al. (1982) described kittiwakes as virtually absent from shallow waters of Bristol Bay in winter, but present in "fair numbers" over shelfbreak and oceanic waters. Probably most of the kittiwakes breeding in colonies in the Bering Sea concentrate in the western portion of their major wintering area south of the Aleutians.

Northward displacement begins in mid-March with intensive movements occurring through straits of the eastern Aleutian ridge in April. Fall migration through Unimak Pass occurs from the middle of September and into late October (Nelson 1976). For the eastern Bering Sea population, there is a broad and gradual movement from breeding colonies to wintering areas south of the Aleutians.

The feeding method of kittiwakes is primarily dipping; however, surface-seizing and occasionally shallow pursuit-diving is employed (Hunt et al. 1981a). Fish are primary prey, but crustaceans (euphausiids, amphipods) and cephalopods are also consumed. In the North Aleutian Shelf area, euphausiids were heavily preyed upon during May (Troy and Johnson 1987).

Common Murre (*Uria algae*).

Both Common and and Thick-billed murres (*U. lomvia*) are abundant and widespread in the southeastern Bering Sea. The species differ in many aspects of their biology and distribution; it is unfortunate that it is frequently difficult to distinguish between them during surveys. The available information suggests that Common Murres are much more numerous within the study area, and thus they are emphasized here.

Within our area of interest, relatively few (approximately 17,000) murres nest. Of these, the vast majority are Common Murres although both species are present. Murres make greatest use of the study area during migration and winter. A substantial number of subadult (nonbreeding) birds may summer along the Bering Sea coast of the study area (D. Forsell, USFWS, pers. comm.).

Autumn migration through Unimak Pass is also quite protracted, extending from late July through October. Peak movements have been recorded during the last week of August and again during the middle of October (USFWS, unpubl. data). The return spring migration through Unimak Pass into the Bering Sea commences in late March, peaks in late April, and continues into May.

Our aerial survey data (Table 1) show peak numbers of murres in Unimak Pass during late winter and spring. Numbers were rather variable and suggest considerable local movement. During February 1986, murres were the most numerous species in this area. Their distribution on occasion appeared to parallel (to the west) the distribution of Crested Auklets. During the January 1985 cruise, some 100,000 murres were estimated to have been seen on a single occasion in this region.

Murres feed by diving, often attaining depths of 110-130 m (Forsell and Gould 1980). Fish are the principal prey, but invertebrates are often an

important constituent of the diet. Common Murres tend to feed within a few km of shore in water 50 m or less in depth, whereas Thick-billed Murres may feed tens of kilometers to sea in deep water (Roseneau and Springer 1982). Common Murres prey on nearshore mid-water fishes (e.g., cod, sand lance, and capelin), whereas Thick-billed Murres use demersal fishes. Invertebrates consumed by both species, in approximate order of importance, include shrimps, amphipods, euphausiids, cephalopods and polychaetes (Roseneau and Springer 1982). There is considerable regional variability in diet; murres on the Pribilof Islands take walleye pollock extensively, whereas murres in Norton Sound prey on sand lance and arctic cod (Hunt et al. 1981a).

Whiskered Auklet (*Aethia pygmaea*).

The Whiskered Auklet is known to nest only on some 40 islands in the Aleutian chain; all but 9 of these are in the Fox Island group. The total population is estimated to be at least 25,000 (Byrd and Gibson 1980), although colony censuses have documented breeding sites of only 6,800 birds (Sowls et al. 1978, Nyswander et al. 1982). This species is particularly difficult to census and it is likely that additional breeding sites will be found.

Whiskered Auklets are less colonial than other *Aethia* auklets, having widely scattered nest sites (Nyswander et al. 1982). On Buldir Island nests are located in talus or under beach boulders, in cavities similar in size to those of Least Auklets (Knudtson and Byrd 1982). Whiskered Auklets lay a single egg.

Whiskered Auklets have been seen in large flocks along the Aleutian chain. The spring distribution tends to be more clumped than the summer distribution. In the Andreanof Islands of the Aleutian chain, Byrd and Gibson (1980) found a greater number of Whiskered Auklets in spring than during the breeding season. Areas in the Aleutian chain where concentrations have been noted include Tigalda Island to Baby Pass (particularly Baby Pass and Avatanak Strait), Unimak Pass, Herbert Island to Yunaska Island, near Seguam Island and Great Sitkin Island, near Segula Island and at Buldir Island. Large flocks (up to 10,000) may be found in tide-rip areas (Byrd and Gibson 1980; Gould et al. 1982).

In winter, Whiskered Auklets are presumed to be distributed near the breeding areas (Byrd and Gibson 1980). In November 1964, at least 1100 Whiskered Auklets collided with a ship in the Islands of the Four Mountains (Dick and Donaldson 1978).

Whiskered Auklets feed by diving (Ashmole 1971). Feeding concentrations are nearly always restricted to tide-rip areas (Byrd and Gibson 1980, Nyswander et al. 1982). Little is known of food habits, but limited data suggest that they feed primarily on crustaceans, including copepods, amphipods, larval crabs, and isopods. Mollusk eggs and fish have also been reported as food items (Day 1980).

Crested Auklet (*Aethia cristatella*).

The Crested Auklet has its population center in the Bering Sea where an estimated two million nest in Alaskan waters. The nesting biology of this species will not be elaborated upon as it is not known to nest in our area of interest although large colonies are found to the west in the Aleutian chain.

Overall, insufficient data are available to accurately describe the wintering distribution of auklets. Most small auklets leave the Bering Sea in fall, wintering along the Aleutian chain and in the open North Pacific. Kodiak Island is a known wintering area for Crested Auklets (Gould et al. 1982). A large concentration of Crested Auklets was found in the Bering Sea north of Unimak Island as part of the NAS investigation (Troy and Johnson 1987); population estimates indicated that hundreds of thousands of birds were present.

Crested Auklets feed by diving (Ashmole 1971) and specialize in preying on zooplankton at moderate (≈ 40 m) depths (Hunt et al. 1981a). At the Pribilof Islands, Crested Auklets take mostly euphausiids, with secondary reliance on amphipods (Hunt et al. 1981a). Searing's (1977) results at St. Lawrence Island indicated that Crested Auklets were almost completely dependent on calanoid copepods. Unfortunately, no auklets were collected as part of the NAS investigations to determine their winter diet in this area.

Tufted Puffin (*Fratercula cirrhata*).

The Tufted Puffin is the most numerous breeding seabird in the study area, having an estimated breeding population in excess of 700,000. Not surprisingly, they are also frequently encountered in high densities during aerial and, especially, shipboard surveys. High densities often occur in areas well removed from the nesting colonies.

Tufted Puffins have a wide nesting distribution, extending from northern Alaska (Cape Lisburne) south to California. Of a worldwide population of 6.25—8 million, perhaps 25% nest in the eastern Bering Sea. Within Alaska, most of the major colonies occur within our study area.

Wehle (1980) has summarized information on all puffin species; unless otherwise specified, the following information is drawn from his work. Tufted Puffins usually nest in earthen burrows on cliff edges of sea slopes. They lay only one egg and are apparently capable of re-laying if their first egg is lost. Breeding phenology on Buldir Island was as follows: arrival before 1 May; peak laying 5-19 June; peak hatching 19 July-2 August; fledging 2-15 September (G.V. Byrd and R.H. Day, unpublished data). Food availability and feeding conditions appear to influence the duration of the nestling period. Most young are flightless when they leave the nest. Fledging success

(young fledged per eggs hatched) was 60-70%. Most chick mortality occurs within two weeks after hatching.

While on the colonies, these birds feed over the continental shelf, seldom straying beyond it (Harrison 1977; Gould 1977, 1978). Following breeding, Tufted Puffins immediately resume a pelagic existence and do not linger over inshore waters near the colonies. This species has no well-defined migration. The population disperses over the open ocean, usually off the continental shelf, following breeding. Occasional large concentrations have been sighted in tide-rip areas in Aleutian passes (Hunt et al. 1981c, Gould et al. 1982). By November, birds are seldom found over the continental shelf and most have left the Bering Sea.

Puffins feed by pursuit-diving, mostly within 15 m of the surface. Generally, fish are the most important component of their diet, although in some areas squid have been found to be important. Crustaceans are consumed in lesser amounts. Sand lance and capelin are the most common prey items fed to nestling puffins, and growth rates of young are the greatest when these fish predominate in food loads brought to nestlings. When the primary prey species are not available, Tufted Puffins tend to prey mainly on cephalopods, or on cod, sculpin, and greenlings.

METHODS

Distribution and Abundance

The distribution and abundance of marine birds were assessed using shipboard surveys. Shipboard counts suffer from the problem that the organisms being censused can move much more rapidly than the counter; this fact alone makes reliable density estimation impossible (Burnham et al. 1980). Many *ad hoc* methods of minimizing this inherent bias have been employed but their accuracy is unverifiable. Surveys near shore are impossible using deep-draft ships (the minimum sampling depth from the R/V *Miller Freeman* was approximately 20 m, and much more in areas of irregular bottom). On the other hand, use of a ship as a sampling platform permits more detailed study of the smaller organisms that are missed or cannot be identified from the air. The ship also allows more precise documentation of certain important behaviors that cannot be ascertained from the air. Most importantly, use of a ship permits concurrent measurements of prey availability and oceanographic conditions—information that is critical when trying to determine correlative and/or probable causative factors for bird and marine mammal distributions.

Counts of marine birds were made during three cruises of the R/V *Miller Freeman*—fall 1986 (18 Sept. - 7 Oct.), winter 1987 (14 Feb. - 9 Mar.), and spring 1987 (21 Apr. - 14 May). Surveys were made while the ship was at or near full speed (≈ 15 kts). Transects were defined as 10-minute intervals as is

the customary protocol for conducting marine bird surveys in Alaska. The biologist censused from the flying bridge using a 90° or 180° arc. We attempted to repeat as close as possible all major survey tracks each cruise (Figs. 1-3) and to augment coverage in areas of particular interest when concentrations were found.

Birds were recorded as being in one of four distance increments parallel to the course of the boat: 0-100m, 100-200m, 200-300m, and >300m. Calculations of densities were based on the first three bands only; the fourth zone was used to record off-transect sightings of major seabird concentrations and whales.

During the survey of each transect, location and environmental conditions were recorded. The most important characteristics were time, coordinates of starting and end points, speed, and depth. Weather information, including cloud cover, sea state, precipitation, wind speed, and air and sea surface temperatures were obtained hourly from the ship's log.

Analyses included tests for differences in abundance among cruises as a measure of seasonal differences in abundance. The major summary analysis of the marine bird studies is a compilation of transect results by water mass as delimited in Chapter 2 (PHYSICAL PROCESSES AND HYDROGRAPHY) of this volume. These same water masses were also used to characterize prey, forage fish and zooplankton, abundance patterns.

Two of the water masses, the 'Gulf of Alaska Water' (GAW) and the 'Alaska Coastal Water' (ACW) were subdivided into northern and southern (Bering and Pacific) masses. In the case of the Gulf of Alaska Water, the two regions were discontinuous and hence logically analyzed separately. As discussed earlier, the Alaska Coastal Water retained it's integrity as it passed through Unimak Pass. However, based on prior studies and the nitrate data, we anticipated that effects of potential upwelling would be manifest on the Bering Sea component of this water mass but not the Pacific side. The exact point of division had to be selected subjectively; we used Seal Cape, the narrowest portion of the Pass, as the dividing point. Thus, most of Unimak Pass itself is in the northern portion of the Alaska Coastal Water mass.

Food Habits

Stomachs of birds shot at sea from small boats were used for food habits analyses. Species and numbers of birds collected, as well as dates and locations of collections, are shown in Table 4.

Shortly after each collection was made, a solution of 5% formalin was injected into the birds to prevent post-mortem digestion of food material. As

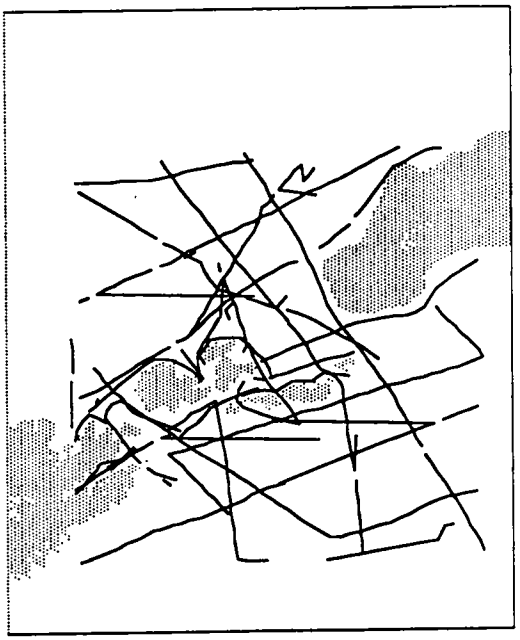


Figure 1. Transect lines for marine bird surveys during fall, 1986, Unimak Pass area, Alaska.

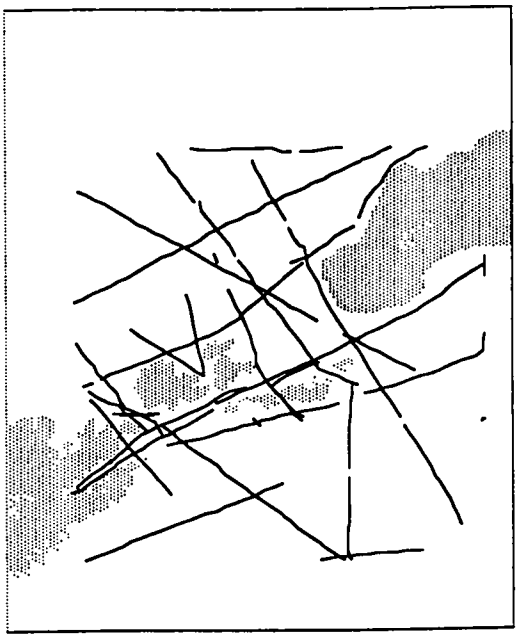


Figure 2. Transect lines for marine bird surveys during winter, 1987, Unimak Pass area, Alaska.

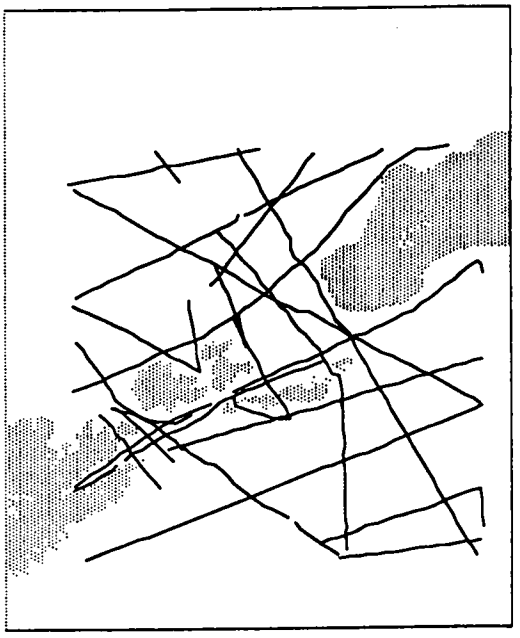


Figure 3. Transect lines for marine bird surveys during spring, 1987, Unimak Pass area, Alaska.

Table 4. Dates and locations of birds collected for food habits studies in the Unimak Pass area, Alaska.

Cruise	Date	Station		No. and Species Collected*
Fall	25 September 1986	17.9		10 STSH
	27 September 1986	10.3		5 WHAU
	4 October 1986	????		5 TUPU
	6 October 1986	26.2		1 TUPU, 4 WHAU
Winter	1 March 1987	9.5		5 WHAU
	3 March 1987	9.2		3 COMU
	3 March 1987	Derbin Str.		2 WHAU
	6 March 1987	21.3		2 WHAU, 9 CRAU
Spring	30 April 1987	22.8		1 COMU
	30 April 1987	8.1		5 WHAU
	2 May 1987	53°51.6'N	165°52.1'W	4 COMU, 2 TUPU
	10 May 1987	31.2		3 COMU, 2 TUPU

* STSH = Short-tailed Shearwater, COMU = Common Murre, TUPU = Tufted Puffin, WHAU = Whiskered Auklet and CRAU = Crested Auklet.

soon as possible thereafter, the birds' stomachs were removed and preserved in 10% formalin in whirlpacks for subsequent laboratory analysis.

In the laboratory, each stomach was removed from its whirlpack and stomach contents were washed into a 153 μm sieve. Contents were sorted and the food items identified and counted. Identifications were made to species when possible. When no identifiable parts were present, an "intelligent guess" as to contents was made. For example, unknown crustacean parts would be recorded as *Thysanoessa* spp., and not as unidentified crustacea, if other birds collected in the area had been eating *Thysanoessa*. Subsampling was undertaken when the total sample weight exceeded about 10 g. A subsample of 1-3 g was taken such that the subsample was 1/5, 1/10 or 1/20 of the total weight.

For each prey species present in a sample, length measurements were made of up to 10 randomly-selected individuals. Measurements were made only on intact invertebrate items. When only otoliths of fish were found, fish lengths and estimated weights at ingestion were calculated following Springer et al. (1984). The proportion of estimated weight ascribable to a given fish taxon was used to calculate the amount of unidentifiable fish material ascribable to the same taxon.

RESULTS

Distribution and Abundance

Seasonal Abundance

Abundances of most marine bird species differed markedly among the three cruises (Table 5). Of the species sufficiently numerous to permit statistical testing for differences in abundance (testing the null hypothesis that the number of birds per sampling effort was not different among cruises), all had highly significant departures from equal abundance among cruises.

Fall. Most species peaked in abundance during the fall cruise. This was particularly true of procellariids (except Leach's Storm-Petrel), larids, and puffins. Although many species were relatively common during fall, the total density of marine birds was lower than that observed during the winter, and considerably higher than during the spring cruise.

Despite the relative abundance of most species during the fall, a few species comprised most of the total. Short-tailed Shearwater was overwhelmingly the most common species, accounting for almost two-thirds of all birds seen. Next in abundance was Black-legged Kittiwake, which accounted for an additional 15% of all sightings. Three additional species were common (here defined as occurring at densities ≥ 10 birds/km^2)—Whiskered

Table 5. Densities of marine birds based on results of ship-based transects, Unimak Pass area, Alaska. Test results for differences in abundance among cruises (seasons) are shown.

SPECIES	Fall 86	Winter 87	Spring 87	Chi-sq	prob
Loon	**0.024**	0.007	0.006	11.439	< 0.005
Western Grebe	0.001	0.000	0.000		
Black-footed Albatross	**0.045**	0.000	0.000	57.415	< 0.005
Laysan Albatross	0.009	0.000	0.012		
Northern Fulmar	**9.927**	5.323	5.068	1522.335	< 0.005
Mottled Petrel	0.005	0.000	0.000		
Sooty Shearwater	**0.931**	0.000	0.021	1126.927	< 0.005
Short-tailed Shearwater	**186.282**	0.005	39.123	162407.300	< 0.005
Fork-tailed Storm-Petrel	**1.424**	0.002	0.079	1615.463	< 0.005
Leach's Storm-Petrel	0.001	0.000	**0.024**	28.376	< 0.005
Red-faced Cormorant	*0.017*	0.167	0.155	90.256	< 0.005
Cormorant	0.048	**0.488**	0.186	292.788	< 0.005
Tundra Swan	0.000	0.002	0.000		
Emperor Goose	0.003	**0.025**	0.000	28.492	< 0.005
Canada Goose	**0.024**	0.000	0.001	27.007	< 0.005
dark goose	**0.023**	0.000	0.000	28.707	< 0.005
King Eider	0.000	**0.483**	0.000	685.750	< 0.005
Eider	*0.003*	0.025	0.019	12.694	< 0.005
Harlequin Duck	0.005	0.007	0.007		
Oldsquaw	0.000	**1.901**	0.219	2160.613	< 0.005
Black Scoter	0.007	0.003	0.003		
White-winged Scoter	0.000	**0.049**	0.007	52.045	< 0.005
Merganser	0.001	0.000	0.000		
duck	0.001	0.002	0.000		
Bald Eagle	0.001	0.013	0.003		
Peregrine Falcon	0.007	0.000	0.001		
Gyrfalcon	0.001	0.000	0.000		
plover	**0.025**	0.000	0.000	32.085	< 0.005
Black Oystercatcher	0.000	0.000	0.001		
Wandering Tattler	0.000	0.000	0.001		
Ruddy Turnstone	0.003	0.000	0.000		
Least Sandpiper	0.000	0.000	0.001		
Rock Sandpiper	0.001	0.000	0.000		
Dunlin	0.005	0.000	0.000		
small Sandpiper	0.005	0.000	0.001		
Phalarope	**3.527**	0.000	0.000	4459.765	< 0.005
Jaeger	**0.043**	0.000	0.012	33.634	< 0.005
Mew Gull	**0.040**	0.012	0.000	32.889	< 0.005
Herring Gull	0.004	0.002	0.001		
Glaucous-winged Gull	**5.124**	3.120	2.304	835.417	< 0.005
Glaucous Gull	0.004	0.002	0.001		
Black-legged Kittiwake	**42.090**	2.370	1.712	44620.640	< 0.005
Red-legged Kittiwake	**0.039**	0.000	0.007	34.713	< 0.005
Sabine's Gull	0.021	0.000	0.000		
Arctic Tern	**0.023**	0.000	0.000	28.707	< 0.005
Aleutian Tern	0.003	0.000	0.000		
Tern	0.007	0.000	0.000		
Common Murre	0.390	**8.681**	1.560	7922.198	< 0.005
Thick-billed Murre	0.004	0.263	**2.463**	2757.625	< 0.005

Table 5. (cont.)

SPECIES	Fall 86	Winter 87	Spring 87	Chi-sq	prob
Murre	0.144	**14.177**	4.724	11431.560	< 0.005
Pigeon Guillemot	*0.001*	0.103	0.154	104.519	< 0.005
Murrelet	0.176	0.017	**0.859**	735.240	< 0.005
Whiskered Auklet	16.289	*11.007*	15.348	701.360	< 0.005
Crested Auklet	0.122	**317.751**	4.768	436878.900	< 0.005
Auklet	3.890	**58.459**	0.333	70688.090	< 0.005
Rhinoceros Auklet	0.008	0.000	0.000		
Tufted Puffin	**9.904**	0.077	0.495	11221.500	< 0.005
Horned Puffin	**0.180**	0.030	0.022	134.230	< 0.005
alcid	0.027	*0.008*	0.039	11.550	< 0.005
Common Raven	0.004	0.007	0.000		
Water Pipit	0.000	0.000	0.010		
pipit	0.000	0.000	0.001		
Savannah Sparrow	0.000	0.000	0.001		
Lapland Longspur	0.005	0.000	**0.055**	60.312	< 0.005
passerine	**0.128**	0.000	0.007	145.077	< 0.005
Total	281.031	424.588	79.822		
Area Sampled (km^2)	748.772	593.974	670.452		

Auklet, Northern Fulmar, and Tufted Puffin. These five species accounted for 94% of the birds seen.

Winter. The highest overall density of marine birds occurred during the winter cruise. The sightings were, however, restricted to a smaller set of species than was the case during the fall. At least three-quarters of all birds enumerated were Crested Auklets, and probably many more Crested Auklets were included as unidentified auklets, the second most common species group. Murres were the next most numerous group, although they were an order of magnitude less numerous than the auklets. Of the identified murres, Common Murres were overwhelmingly in the majority, and most unidentified murres were probably of this species. The only other species occurring in densities $\geq$ 10 birds/km^2 was Whiskered Auklet. Although the density data show this species to be less common during this cruise than during the other two cruises, it is likely that the density was underestimated during the winter cruise. The winter deficit of Whiskered Auklets is probably hidden in the unidentified auklet category. This species often mixed in large groups of Crested Auklets such that it was impossible to accurately separate them. Many mixed groups had to be coded simply as auklets. These three species—Crested Auklet, Common Murre, and Whiskered Auklet—accounted for approximately 97% of all marine birds present during the winter cruise.

Several of the uncommon species occurred in their highest densities during the winter cruise. These were cormorants (most of those identified were Red-faced Cormorants), Emperor Goose, and seaducks (particularly King Eider, Oldsquaw, and White-winged Scoter). Most of these species were quite rare in the areas sampled by the ship.

Spring. The spring season had the lowest densities of marine birds of all our cruises. Overall densities were only one-fifth of those recorded during the winter cruise, which ended about a month prior to the start of the spring cruise. This illustrates the dynamic nature of bird populations during times of migration. It was obvious that most winter birds had left for breeding areas and that few of the summer birds were yet present. Indeed, the most numerous species during the spring cruise, Short-tailed Shearwater, was recorded in appreciable numbers only towards the end of the cruise. The only other common species observed during this cruise was Whiskered Auklet. (Note that Whiskered Auklet was the only species that was considered common during all cruises.) These two species comprised 68% of all the sightings.

The most diverse avifauna was recorded during the spring cruise. It was not dominated as much by a few species of overwhelming abundance as it was in fall and winter.

Among the less common species that made up a sizable proportion of the total birds seen were Northern Fulmar, murres, and Crested Auklet. Thick-billed Murres made up the largest proportion of the identified murres and reached their peak abundance during this cruise. Rarer species that reached their peak abundance during the spring cruise were Leach's Storm-Petrel, murrelets (Ancient Murrelets in particular), and Thick-billed Murre. That migration was underway was exemplified by occurrence of passerine birds, especially Lapland Longspur, during the marine transects.

Spatial Distribution

Fall. The greatest concentrations of marine birds during the fall cruise were in the Bering Sea or among the Krenitzin Islands; relatively few birds were seen in the Gulf of Alaska by comparison (Fig. 4). Comparison of the distribution of the marine birds revealed a rather consistent area of concentration in the northern portion of Unimak Pass, just north of Akun Island. Northern Fulmar, Short-tailed Shearwater, phalaropes, Black-legged Kittiwake, and Tufted Puffin all occurred in large numbers in this area.

Akutan Pass was another concentration area. This pass itself was the major concentration area for Whiskered Auklets (thousands of birds). Whiskered Auklets were closely associated with the Krenitzin Island group; however, except for Akutan Pass itself, the largest aggregations were in the Gulf of Alaska, south of the passes between the islands. The highest concentration of Common Murres was also within Akutan Pass but this species was not numerous during this time of year. A major concentration of Short-tailed Shearwaters was present in the Bering Sea just north of Akutan Pass.

A few other less common species also peaked in abundance in the passes and straits region among the islands. These included cormorants (Fig. 5), murrelets (especially in Beaver Inlet), and Horned Puffins (south side of Unimak Island). The only species showing a particular affinity for the Gulf of Alaska away from land was Black-footed Albatross, which occurred primarily in the deep water at the southern boundary of the study area.

Winter. The winter season brought considerable change in the species composition of the avifauna. Waterfowl were prominent only during this season. Even from shipboard surveys, seaducks were regularly encountered. Although waterfowl were present in the straits and passes of the Krenitzin Islands (especially Akutan Pass), the coastal waters north of Unimak Island supported their largest concentrations. Prominent in this regard were Cape Sarichef for Oldsquaws and Cape Mordvinof for King Eiders (Fig. 6).

Gulls, similarly to waterfowl, were also more important in winter than in fall. Both Glaucous-winged Gull and Black-legged Kittiwake were common

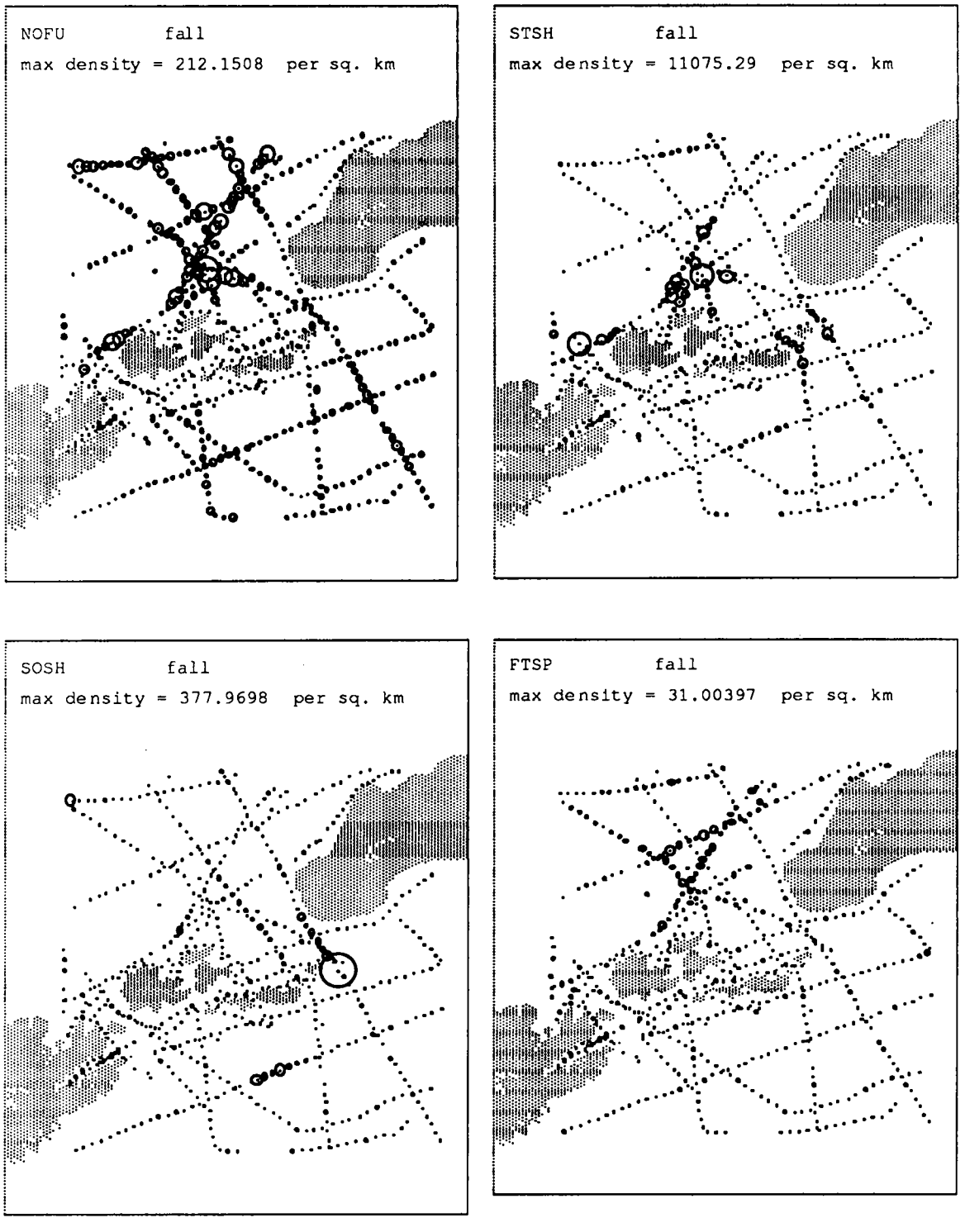


Figure 4. Distribution of marine birds recorded on ship-based transects (each dot represents a transect) during fall, 1986, Unimak Pass area, Alaska. Density of birds is proportional to the area of the circle; the maximum density (largest circle) is listed at the top of each map. (NOFU = Northern Fulmar, STSH = Short-tailed Shearwater, SOSH = Sooty Shearwater, FTSP = Fork-tailed Storm-Petrel)

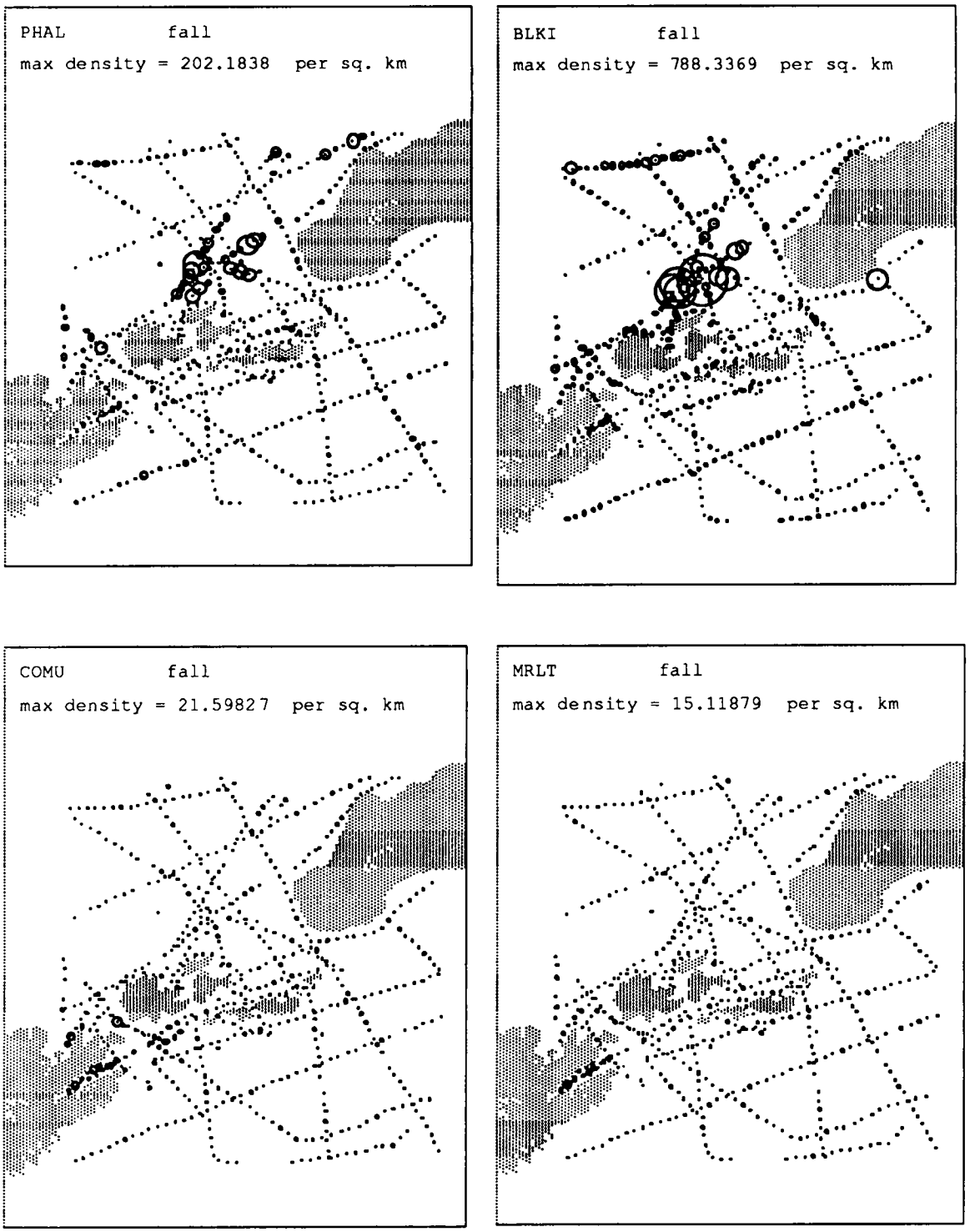


Figure 4 (cont.). (PHAL = Phalarope, BLKI = Black-legged Kittiwake, COMU = Common Murre, MRLT = Murrelet)

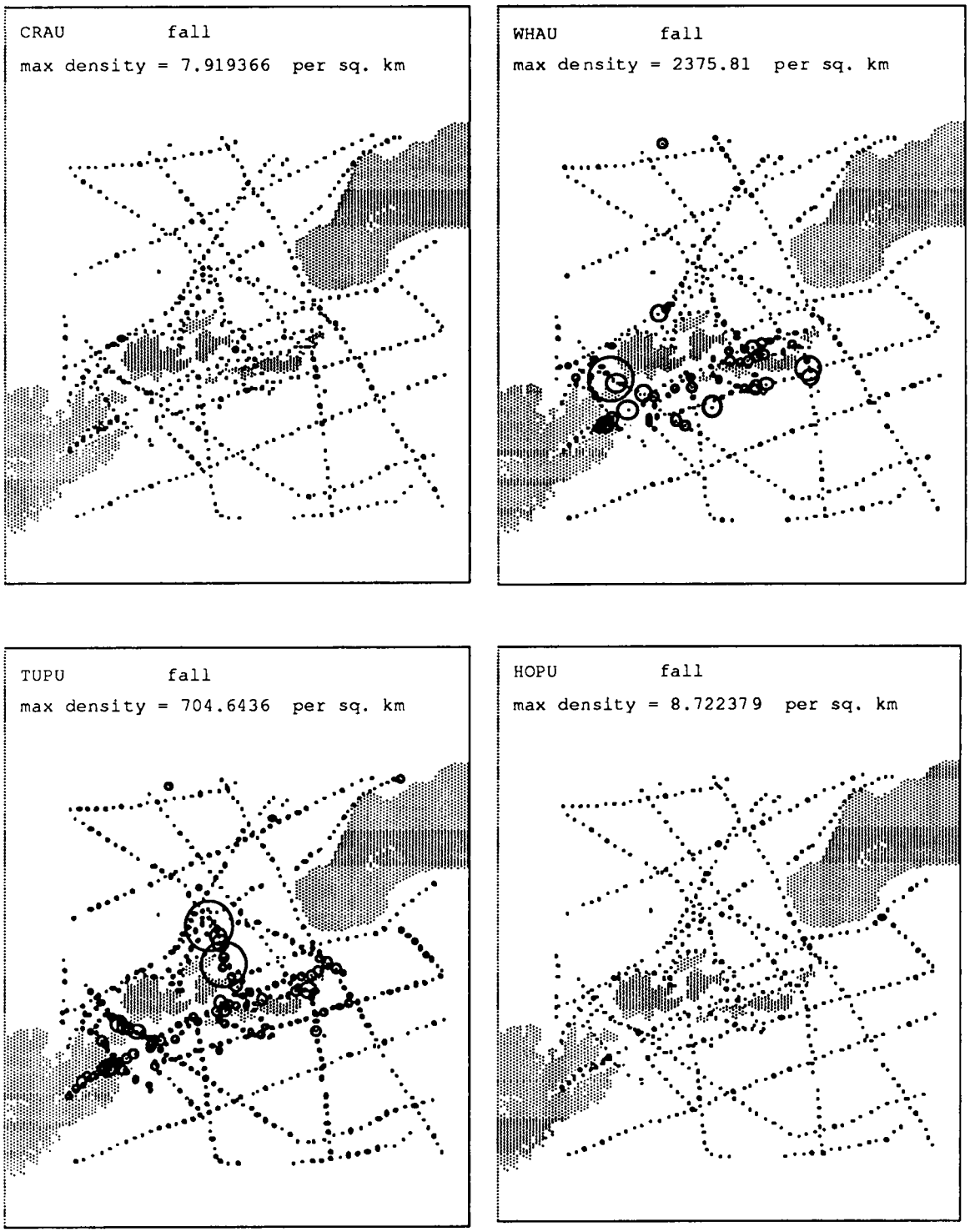


Figure 4 (cont.). (CRAU = Crested Auklet, WHAU = Whispered Auklet, TUPU = Tufted Puffin, HOPU = Horned Puffin)

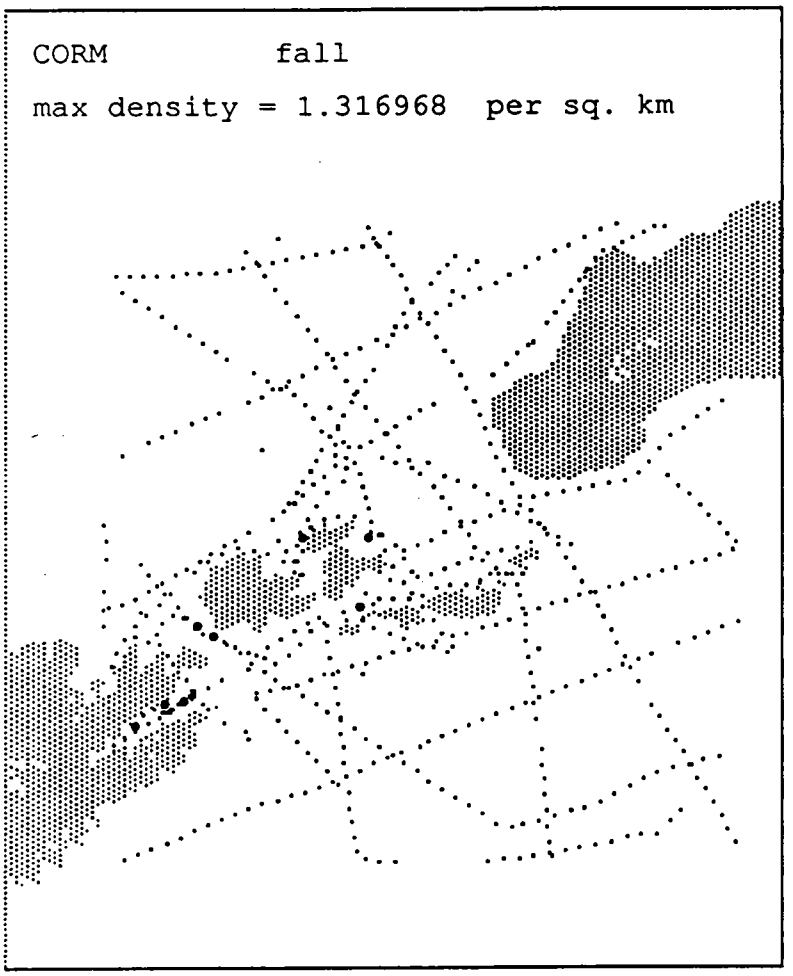


Figure 5. Distribution of cormorants (CORM) as determined from shipboard transects during fall, 1986, Unimak Pass area, Alaska. This species was largely restricted to the straits and passes of the Krenitzin Islands.

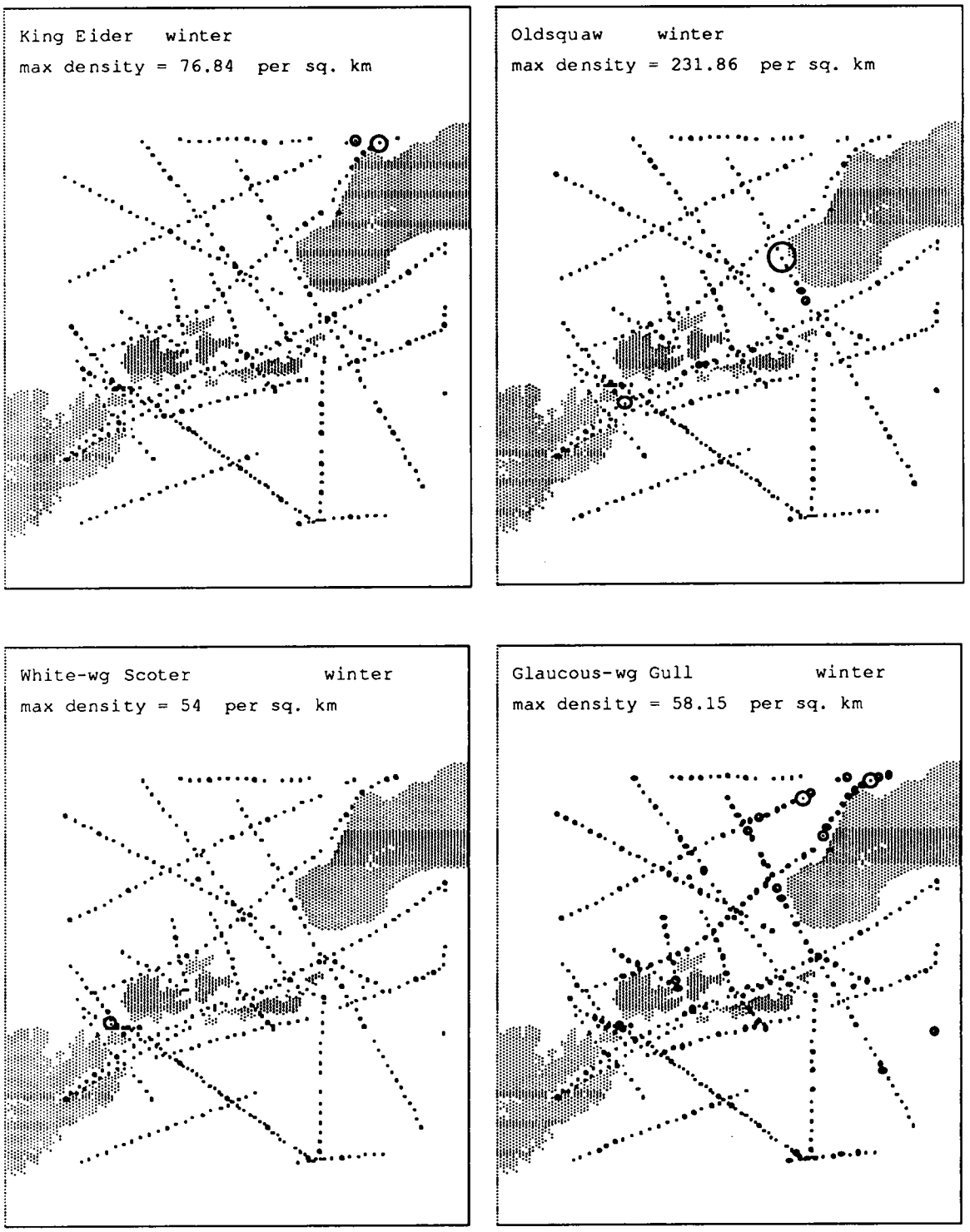
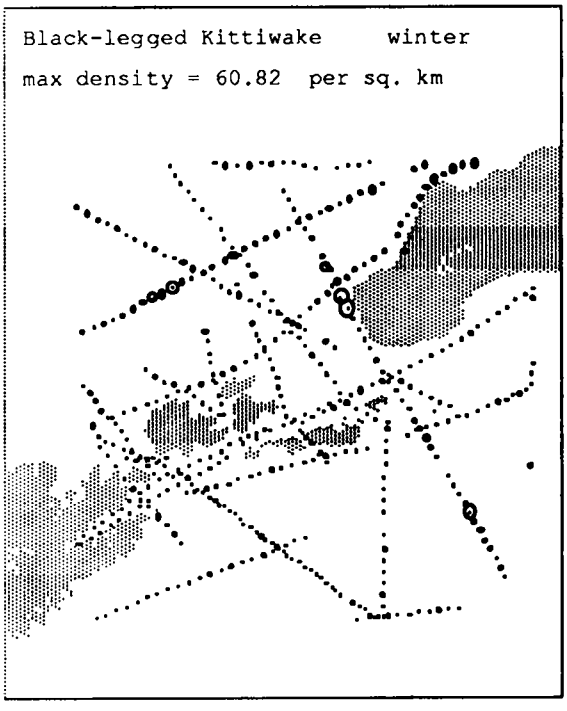
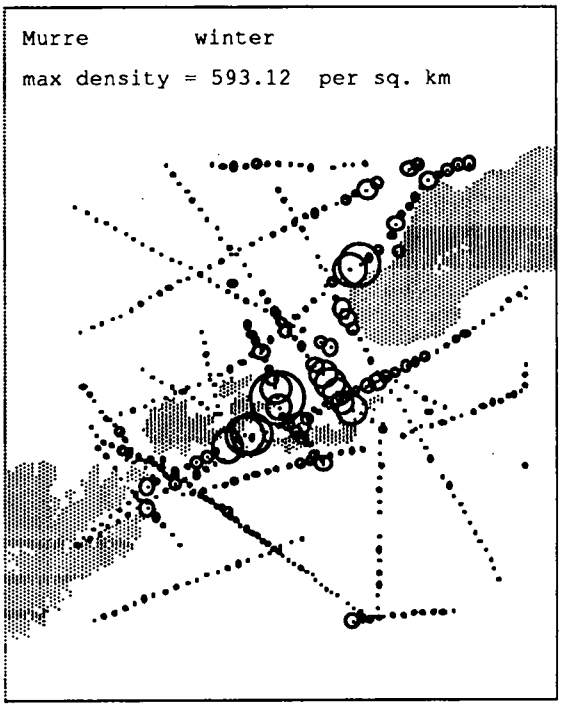
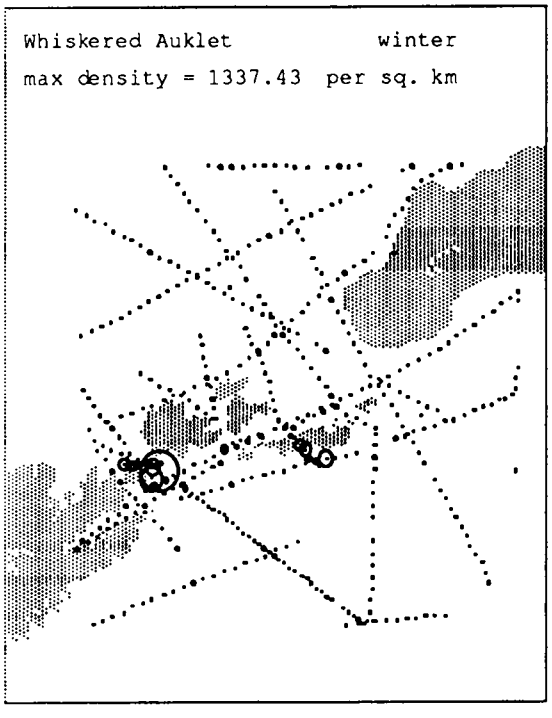


Figure 6. Distribution of marine birds recorded on ship-based transects (each dot represents a transect) during winter, 1987, Unimak Pass area, Alaska. Density of birds is proportional to the area of the circle; the maximum density (largest circle) is listed at the top of each map.







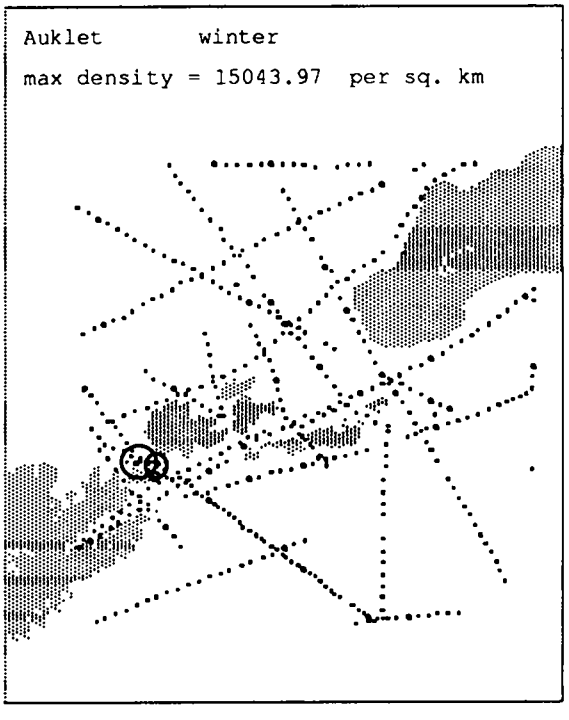


Figure 6 (cont.)

and widespread, but their distributions were dissimilar. Glaucous-winged Gulls were most numerous close to land, especially north of Unimak Island. In contrast, Black-legged Kittiwakes were most numerous in the deeper parts of the study area, both in the Bering Sea and, to a lesser extent, in the Gulf of Alaska. Large numbers were also found in Unimak Pass itself off Cape Sarichef.

Some of the most common birds during winter were murres, primarily Common Murre. Murres also were the birds most characteristic of the passes and straits in our study area. These birds were particularly numerous in Unimak Pass, Avatanak Strait, and the coastal waters north of Unimak Island, especially off Cape Sarichef.

The two species having the highest concentrations of all marine birds were the auklets. Crested Auklet was by far the most numerous species recorded during the winter, locally occurring at maximum densities in excess of 10,000 birds/km^2 (Fig. 7). Whiskered Auklets were also numerous but their densities were an order of magnitude less than those of Crested Auklets. Although overlapping in distribution, the two species of auklets were frequently spatially separated. Both species were abundant in Akutan Pass, with Baby Pass supporting the highest concentrations. The incredible number of auklets in Baby Pass and the fact that both species were mixed resulted in many individuals being unidentified as to species in this area. Whiskered Auklets were restricted to the immediate vicinity of the Krenitzin Islands with the only other concentration area during this cruise being in Derbin Strait. Crested Auklets, in contrast, had their center of distribution in the coastal waters north of Unimak Island; Akutan Pass was a notable but disjunct concentration area for this species.

The areas of greatest bird density in winter were 1) the north side of Unimak Island, 2) Akutan Pass, and 3) Avatanak Strait. This represents a considerable change from the fall cruise in that during winter more birds were found close to land and the concentration areas were farther east in Unimak Pass itself.

Spring. Marine birds were less concentrated in spring than during other seasons. Individual species frequently occupied specific geographic regions of concentration, but their location and extent of concentration varied markedly among the species (Fig. 8). Northern Fulmar, for example, was widespread in the Bering Sea but infrequent elsewhere, the only species so distributed. The gulls continued to be common, with the winter pattern of Glaucous-winged Gulls close to land and Black-legged Kittiwakes in deeper water persisting. The kittiwakes were virtually absent from the Bering Sea (except near the passes), in contrast with their winter distribution.

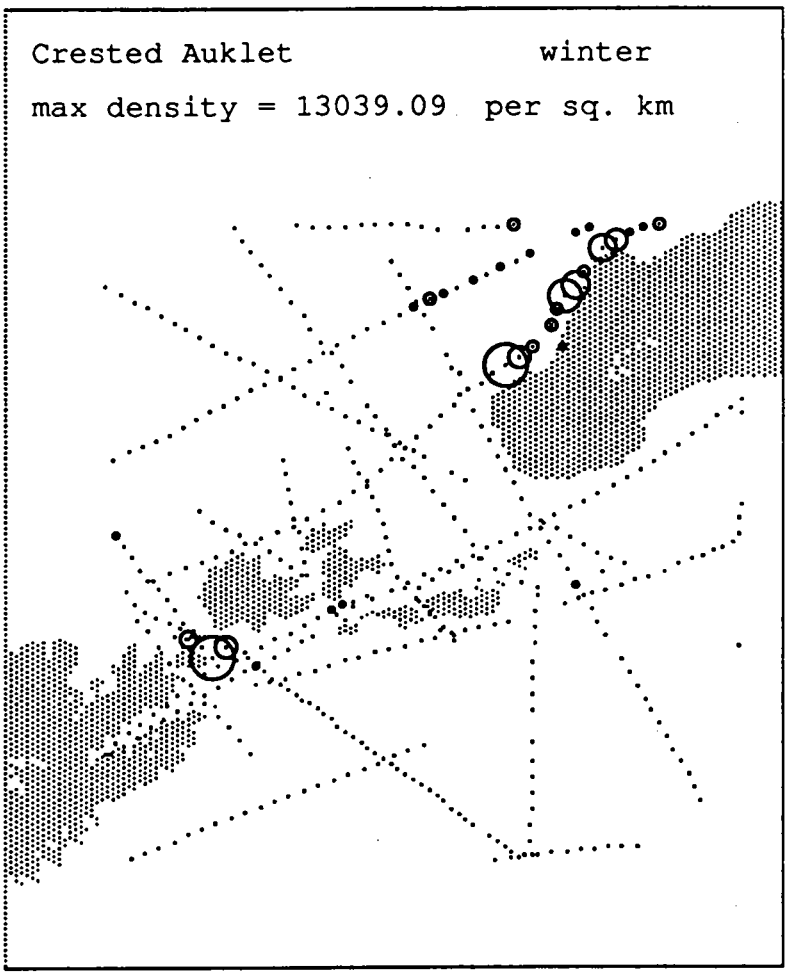


Figure 7. Distribution of Crested Auklets as determined from ship-based transects during winter, 1987, Unimak Pass area, Alaska.

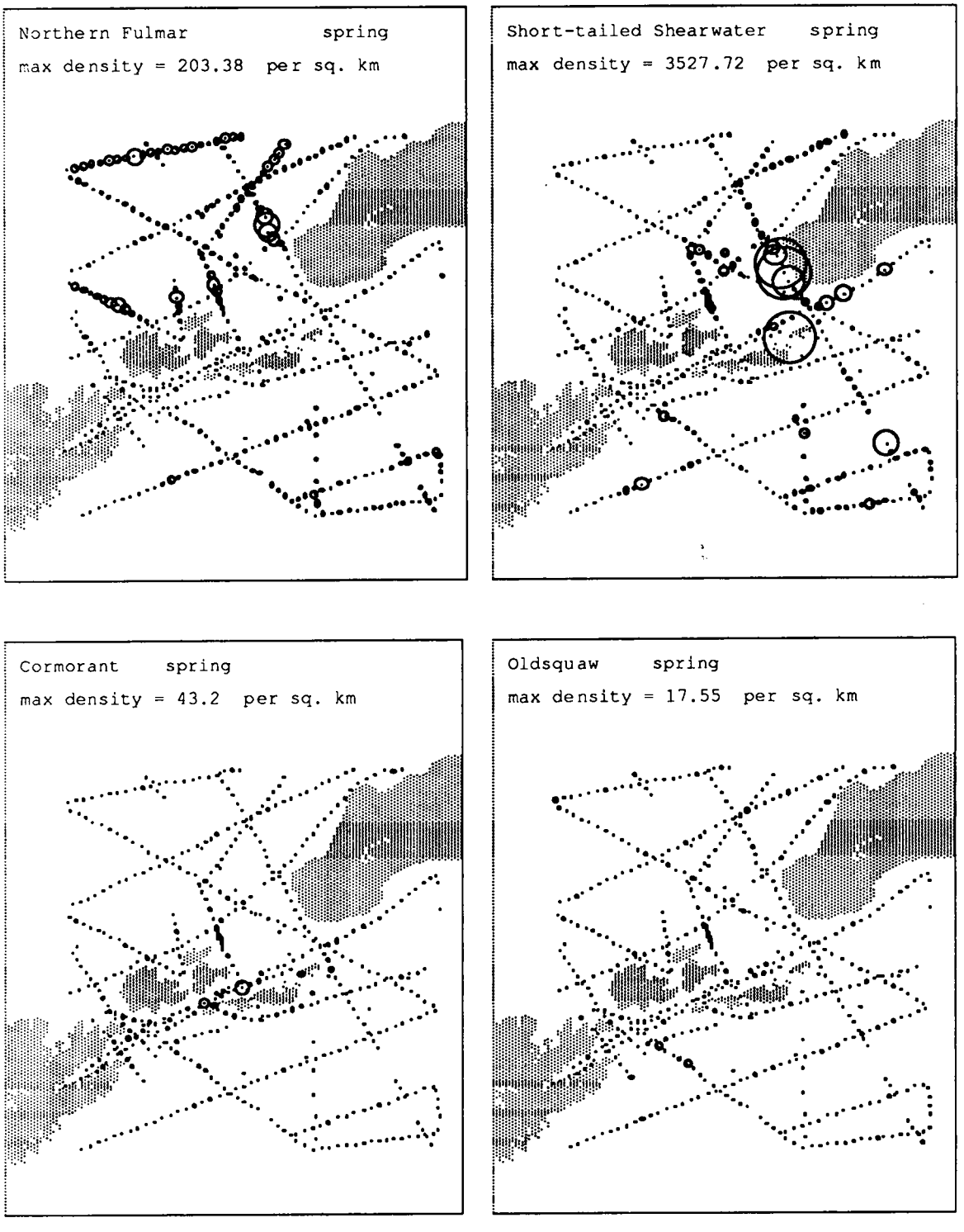
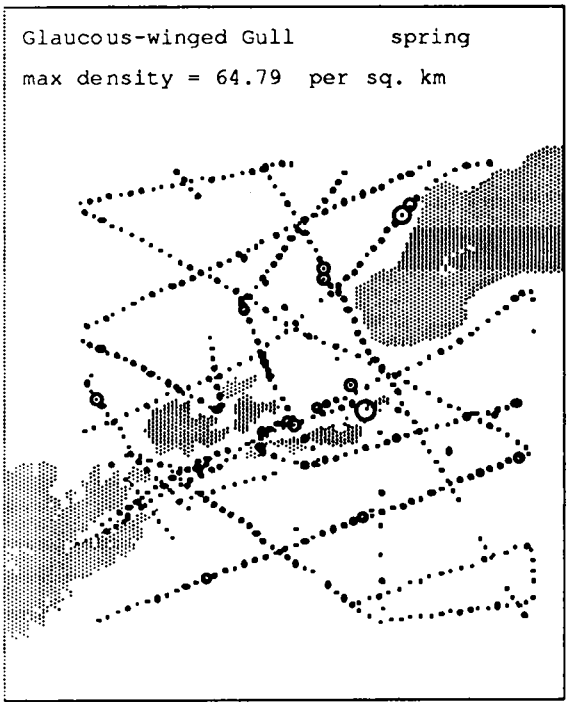
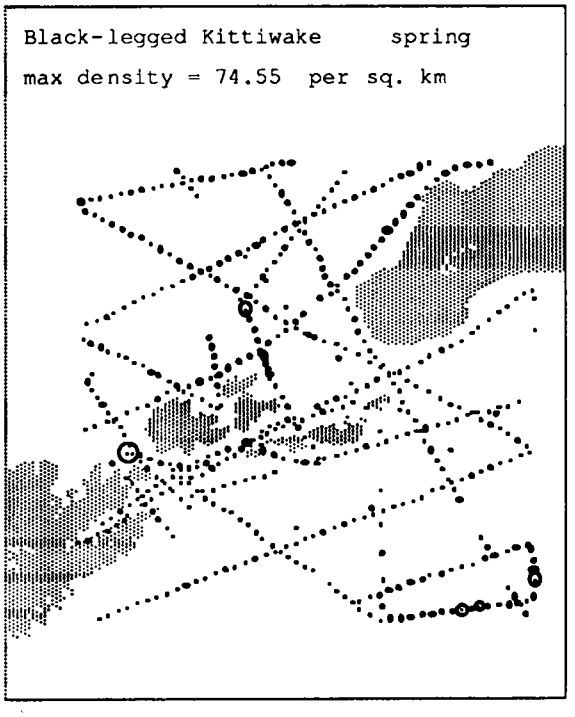
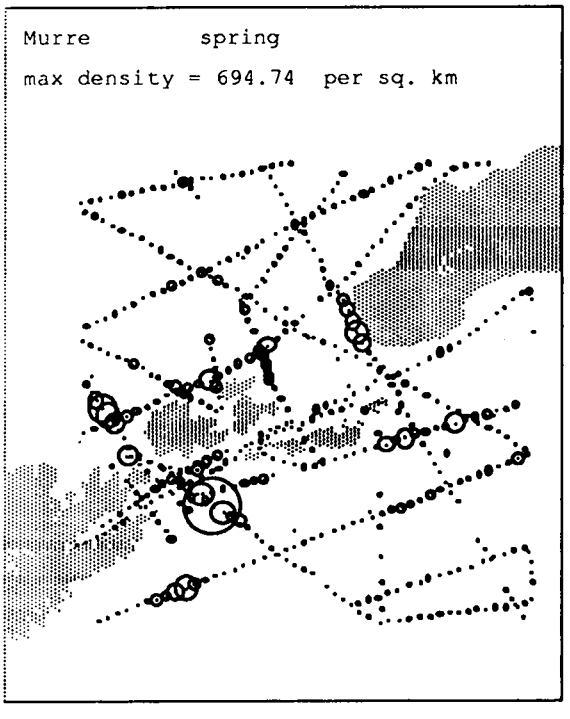


Figure 8. Distribution of marine birds recorded on ship-based transects (each dot represents a transect) during spring, 1987, Unimak Pass area, Alaska. Density of birds is proportional to the area of the circle; the maximum density (largest circle) is listed at the top of each map.







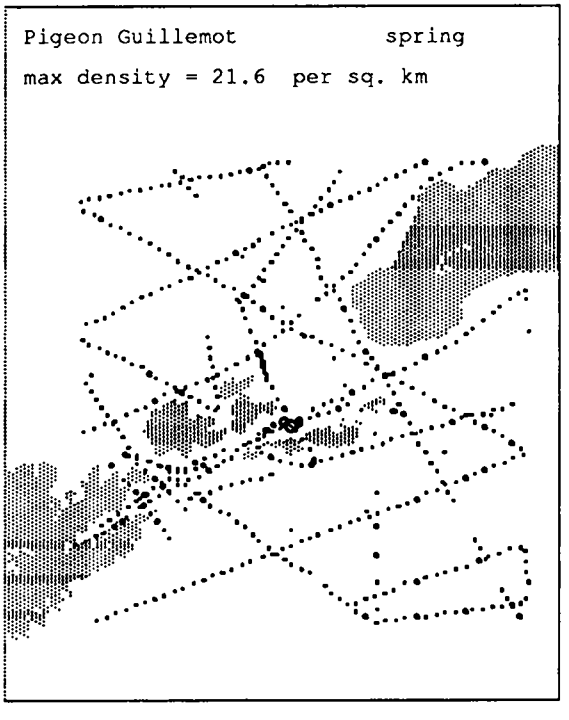


Figure 8. (cont.)

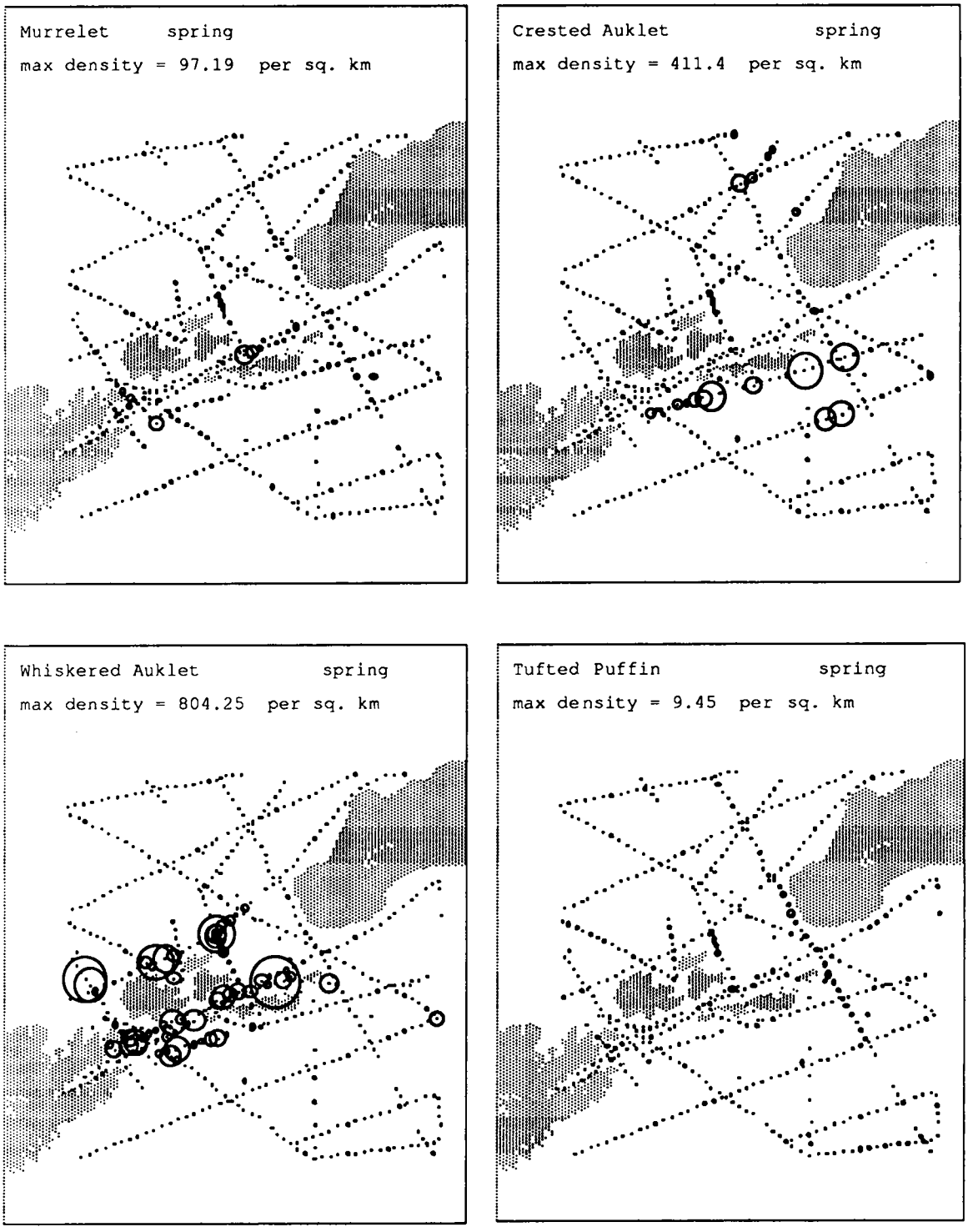


Figure 8. (cont.)

Short-tailed Shearwaters were just starting to arrive in the study area during the cruise. The distribution map (Fig. 8) reveals more birds in the Gulf of Alaska than in the Bering Sea; concentration occurred in the eastern parts of Unimak and Ugamak passes. Some species breeding in the area were more abundant than in winter; these tended to peak in abundance within the Krenitzin Islands area. Examples are cormorants, Pigeon Guillemot, murrelets (primarily Ancient Murrelet), and Tufted Puffins. Murres continued to be one of the most numerous groups, but during spring they were much more dispersed than during the winter and occurred in concentrations off the passes, especially south of Akutan Pass, rather than within the passes and straits as had been observed in winter. Part of the change in distribution might have been due to the higher porportion of Thick-billed Murres recorded during the spring.

The auklets continued to be numerous and to have interesting distributional patterns. The concentration areas of Crested Auklets were not at all coincident with those observed during the winter. In spring this species was found primarily south of the Krenitzin Islands opposite the passes. Whiskered Auklets were much more widespead than during the winter; they were found thoroughout Avatanak Strait and in the Bering Sea opposite the Krenitzin Islands passes. There was a relatively limited area of overlap between these two species (south of Akutan Pass).

Associations with Water Masses

Fall. In fall, marked differences in abundances of marine birds were evident among water masses (Table 6). The highest densities occurred in the Shelf Break Water (SBW) due to the extreme abundance of Short-tailed Shearwaters and Black-legged Kittiwakes in water of this type. During the fall cruise, the spatial extent of this water mass was more extensive than was observed during other cruises, occupying much of the northwest corner of the study area. Shearwaters were also abundant in the adjacent Gulf of Alaska Water north of the islands (GAWn); however, Black-legged Kittiwakes were abundant only in the Shelf Break Water (SBW).

The Alaska Coastal Water was quite depauperate in birds in both the north (ACWn) and south (ACWs) regions. Horned Puffins reached their peak abundance in the southern portion of this water mass; however even here they were quite rare.

Oceanic areas in the Gulf of Alaska (GAWs) had very low bird densities. One species, Black-footed Albatross, was restricted to this area.

Although absolute densities in the Tidally Mixed Water (TMW) were substantially lower than in the more structured water masses to the north,

Table 6. Average densities of the most common marine birds sighted during ship-based transects in fall, 1986, by water mass in the Unimak Pass area, Alaska. The highest density of each species is shown in bold face.

	SBW	TMW	GAWn	GAWs	ACWn	ACWs
Black-footed Albatross	0.00	0.00	0.00	**0.07**	0.00	0.00
Northern Fulmar	**12.92**	0.41	7.31	3.83	0.77	0.21
Short-tailed Shearwater	**265.89**	26.29	139.14	11.62	9.06	2.29
Sooty Shearwater	0.28	0.04	**1.05**	0.63	0.59	0.09
Fork-tailed Storm-Petrel	**3.07**	0.01	0.59	0.08	0.05	0.00
cormorant	0.00	**0.06**	0.00	0.00	0.01	0.05
phalarope	3.93	0.17	**4.96**	0.14	1.75	0.00
Black-legged Kittiwake	**100.71**	1.10	5.52	0.61	1.58	6.27
Common Murre	0.02	**0.47**	0.06	0.08	0.17	0.12
murrelet	0.01	**0.14**	0.02	0.02	0.10	0.12
Crested Auklet	0.02	0.05	**0.20**	0.03	0.01	0.00
Whiskered Auklet	0.96	**22.45**	2.38	2.86	1.21	0.05
Tufted Puffin	1.91	**9.96**	2.13	1.47	0.95	0.94
Horned Puffin	0.03	0.03	0.13	0.04	0.11	**0.99**
Total	**389.75**	61.17	163.48	21.48	16.36	11.13

Table 7. Average densities of the most common marine birds sighted during ship-based transects in winter, 1987, by water mass in the Unimak Pass area, Alaska. The highest density of each species is shown in bold face.

	SBW	TMW	GAWn	GAWs	ACWn	ACWs
Northern Fulmar	0.48	0.47	1.00	0.25	**10.57**	0.18
cormorants	0.22	**0.61**	0.00	0.01	0.14	0.01
Emperor Goose	0.00	**0.03**	0.00	0.00	0.00	0.00
Oldsquaw	0.00	0.26	0.05	0.00	**3.44**	0.00
White-winged Scoter	0.00	0.02	0.00	0.00	**0.07**	0.00
King Eider	0.00	0.02	0.00	0.00	**1.19**	0.00
Glaucous-winged Gull	0.59	0.57	0.78	0.45	**4.43**	0.51
Black-legged Kittiwake	1.76	0.13	1.70	0.41	**2.69**	0.36
Common Murre	0.33	13.01	1.53	1.77	**20.32**	2.42
Pigeon Guillemot	**0.11**	0.10	0.00	0.00	0.00	0.00
murrelets	0.00	**0.01**	0.00	0.00	**0.01**	0.00
Crested Auklet	22.59	80.58	0.08	0.03	**595.64**	3.79
auklets	35.26	**59.26**	0.12	0.00	0.06	0.07
Whiskered Auklet	0.00	**11.47**	0.03	0.04	0.00	0.07
Tufted Puffin	0.00	0.01	**0.08**	0.03	0.03	0.01
Horned Puffin	0.00	0.01	**0.02**	0.01	0.01	0.01
Total	61.34	166.55	5.40	2.99	638.62	7.44

several species were largely restricted to this water mass. Most striking in this regard were Whiskered Auklet and Tufted Puffin. Cormorants, murrelets, and Common Murres were also most frequent in the TMW.

In general, the ACW was used little by birds. Outside of this water mass, bird use of the Bering Sea side of the chain was high relative to that on the Gulf of Alaska side.

Winter. Use of the various water masses during winter differed markedly from the use observed during the fall cruise. The highest densities occurred in the ACW by a large margin (Table 7). Very striking was the contrast between the south and north components; almost all the birds occupied the northern portion. Crested Auklets made up the greatest proportion of birds encountered in this water mass; however, many other species reached their peak abundance here. Other common species in the ACWn were Northern Fulmar and Common Murre. Several species of seaducks and gulls also reached peak abundance in this area.

Likewise, the TMW seemed more important to birds in winter than in fall. Whiskered Auklets were still largely confined to this water mass, but even higher densities of Crested Auklets were seen using these areas. Common Murres were also numerous in TMW, although their densities were not as high as in the Alaska Coastal Water. Most of our encounters with Emperor Geese and cormorants were in Tidally Mixed Waters, though neither species was common in the areas surveyed by the ship.

Gulf of Alaska Water (GAW) had a dearth of birds. The northern portion had slightly more birds than the south. Both Tufted and Horned puffins peaked in abundance in the northern segment (GAWn), but puffins were generally rare throughout this area during winter.

The Shelf Break Water mass (SBW) was much reduced in area during the winter as compared to the fall. Water of this character was identified in two areas, one north of Unalaska Island, the other at the northern extreme of the study area. A more complete picture might have revealed the two parts of SBW to have been connected west of our study area. Moderate densities of birds, almost all auklets (presumably mostly Crested Auklets), were found in this water mass.

Overall, the winter results show that the Gulf of Alaska continued to have relatively few birds, as in fall. Bird use of the western segment of the Bering Sea habitats was greatly reduced relative to the fall cruise, whereas habitats under the influence of the Alaska Coastal Water in the eastern portion were heavily used by marine birds. Tidally Mixed Water was more important to birds during winter than during fall.

Spring. Bird density was more equitable among water masses during the spring cruise than during other times (Table 8), although overall densities were relatively low. The highest densities of marine birds occurred in the Alaska Coastal Water and, although the northern portion was again the most important, the portion south of Unimak Island had more birds than was observed during any other cruise. In both ACWn and ACWs, Short-tailed Shearwaters predominated.

Gulf of Alaska Water had similar overall bird densities in both northern and southern sectors, but the species composition was different between the two. In the south, where densities were highest of all cruises, Common Murres were the most frequent species. In the north, Whiskered Auklets predominated (although this species was more numerous in the Tidally Mixed Water).

In marked contrast to the results of the fall cruise, the Shelf Break Water was the least used in spring of any water mass. No species peaked in abundance in this habitat.

As mentioned above, the Tidally Mixed Water continued to be the major habitat for Whiskered Auklets. Although several species peaked in abundance here—murrelets, Pigeon Guillemot, cormorants—only Whiskered Auklets occurred in appreciable numbers.

Food Habits

Short-tailed Shearwater

We found no significant differences in the diets of four male versus six female Short-tailed Shearwaters in the occurrence of various food taxa (all hypergeometric probabilities >0.05/n, where n = no. of taxa compared). (The birds were not aged, but one of the females had a well-developed brood patch, indicating sexual maturity.) Therefore, we grouped males and females for the following description of shearwater diet.

The 10 birds contained 9,980 food items, of that all but three were *Thysanoessa* euphausiids. Two of the stomachs each contained a single *Parathemisto abyssorum* and a third stomach contained a single squid beak (probably representing a *Gonatus* squid of about 3.8 g, based on equations given in Clarke [1962]).

Food loads ranged from 0.007-34.7 g. Of the euphausiids that were identified to species (many items could be identified only to genus), *Thysanoessa inermis* formed 67-100% of observed diet wet weight in the ten stomachs, *T. spinifera* formed 0-33%, and *T. raschii* formed 0-2%. Overall, *T. inermis* formed 75.3% of identified euphausiid material, *T. spinifera* formed

Table 8. Average densities of the most common marine birds sighted during ship-based transects in spring, 1987, by water mass in the Unimak Pass area, Alaska. The highest density of each species is shown in bold face.

	SBW	TMW	GAWn	GAWs	ACWn	ACWs
Northern Fulmar	4.58	0.12	4.86	1.55	**5.86**	1.32
Short-tailed Shearwater	0.23	1.96	6.21	6.01	**82.53**	27.02
Fork-tailed Storm-Petrel	0.03	0.00	0.02	**0.12**	0.03	0.03
cormorants	0.00	**0.42**	0.01	0.00	0.13	0.05
Oldsquaw	0.20	0.08	0.02	**0.32**	0.16	0.09
Glaucous-winged Gull	0.45	0.85	**0.97**	0.91	2.72	0.90
Black-legged Kittiwake	0.57	0.74	0.94	1.10	**1.20**	0.40
Common Murre	2.21	5.17	4.48	**8.33**	3.14	2.41
Pigeon Guillemot	0.00	**0.23**	0.00	0.00	0.00	0.00
murrelets	0.00	**0.92**	0.10	0.23	0.18	0.30
Crested Auklet	0.00	1.26	0.22	3.83	1.82	**7.57**
auklets	0.00	**0.20**	0.12	0.11	0.16	0.15
Whiskered Auklet	0.00	**16.88**	8.30	2.68	0.03	0.61
Tufted Puffin	0.03	0.25	0.13	0.24	0.26	**0.30**
Total	8.28	29.10	26.37	25.43	**98.23**	41.16

Table 9. Lengths of identified euphausiids found in stomachs of Short-tailed Shearwaters collected in fall, 1986, and spring, 1987, in the Unimak Pass area, Alaska.

Taxon	Mean	S.D.	No. measured
Thysanoessa inermis	11.1	0.7	10
	11.2	1.0	10
	11.8	1.3	10
	11.1	3.8	10
	8.8	5.5	10
	13.7	3.0	10
	7.4	4.9	10
	10.9	1.3	10
all stomachs	10.8	3.2	80
Thysanoessa spinifera	12.4	2.1	8
	12.7	1.5	3
	15.8	6.4	4
	11.4	1.4	10
	12.5	0.6	4
	11.6	4.4	5
	13.6	1.7	5
	12.5	2.0	10
all stomachs	12.8	2.7	49
Thysanoessa raschii	10.3	2.7	6

24.0%, and *T. raschii* formed 0.2%. Identified euphausiids formed 29.7% of total euphausiid wet weight.

Mean lengths of *Thysanoessa inermis* ranged between 7.4-13.7 mm in eight stomachs where measurements were made. *T. spinifera* lengths ranged between 11.6-15.8 mm in eight stomachs. The *T. inermis* and *T. spinifera* present in the stomachs were similar in size (Table 9; Mann-Whitney U = 55; P>0.1).

Tufted Puffin

Ten Tufted Puffins were collected during the study for food habits analysis. Four adults and two juveniles were collected in fall (October), and four adults were collected in spring (May).

In fall, adult diets were dominated by squid (probably *Gonatus* spp.), which represented 57% of prey wet weight in the four stomachs. Squid was followed in order of dominance by gadid sp. (most likely pollock but possibly Arctic cod, *Boreogadus saida* [24.4%], saffron cod, *Eleginus gracilis* [17.7%], and unidentified fish), *Nucella* gastropods, unidentified gastropods, euphausiids, hyperiid amphipods and calanoid copepods (each less than 0.5%).

In the two juveniles collected in fall, squid formed 97.2% of diet wet weight, and unidentified fish comprised 2.5%. Decapods and copepods each contributed less than 0.5% to the juvenile diets.

On a numerical basis, squid (represented mostly by beak remnants) formed 17% of 29 items enumerated in adult stomachs and 95% of the 257 items enumerated in the stomachs of juveniles. Based on known ratios between squid beak lengths and body weights, most of the squid ingested were small; estimated wet weights ranged from 0.2 - 2.4 g. Otoliths and flesh from two unidentified cod and two saffron cod were found in one adult stomach. Estimated mean lengths of the fish were 76 and 15 mm for the unidentified cod (based on otolith-length relationships from arctic cod) and 58 and 7 mm for the saffron cod.

Most of the fall specimens of Tufted Puffin were collected in areas distant from the Krenitzin Islands (near the southern limit of the study area in deep water). Closer to the Krenitzins most puffins were seen carrying fish, and samples of prey brought to chicks in the nesting colonies were predominantly small pollock (S. Hatch, USFWS pers. comm.).

In the spring collection of puffins, one of the females had an empty stomach and the other female and two males contained 101.7 g of food material. Of this amount, 99.6% was *Ammodytes*, 0.4% was unidentified sculpins, and 0.1% was *Nucella* gastropods. Measurable *Ammodytes* were

present in two stomachs, differing significantly in size between the two samples (105 and 18 mm [n=9], vs. 63 and 37 mm [n=8], t=-2.94, P<0.02).

Common Murre

Eleven Common Murres were collected during the study, and all but one stomach contained food. Stomachs of three adult females were analyzed from winter collections and those of seven birds (two adult males, two adult females, two subadult females, and one unaged male) from spring collections.

The three females in winter had been feeding exclusively on two species of *Thysanoessa* euphausiids (9.4 g of total food material in the three stomachs). Identified euphausiids were 26% of the total material; 96% of this was *T. inermis* and 4% was *T. spinifera* . Measurable *T. inermis* were present in two stomachs and were similar in size (grand mean of 17.2 mm; t=1.8, P>0.05). Only two of the seven identified *T. spinifera* were measurable; these were 14.5 and 0.7 mm.

Birds collected in spring contained a total of 163.3 g of food material, but almost all of it (161.6 g) was from two birds. Wet weight composition of the total diet was 98.9% *Ammodytes* (present in two stomachs), 1.0% unidentified fish (present in two stomachs), 0.1% *Thysanoessa* euphausiids (present in three stomachs) and <0.1% *Parathemisto* amphipods and *Gonatus* squid (each present in one stomach). In the two stomachs where *Ammodytes* could be measured, mean lengths were similar (grand mean of 111 mm; t=1.3, P>0.05). The lengths of *Thysanoessa inermis* present in the one stomach where they were measurable ranged from 2.7 to 16.2 mm (n = 10).

Whiskered Auklet

Twenty-three Whiskered Auklets were collected for food habits studies: nine in fall, nine in winter, and five in spring (Table 10).

During fall, the wet-weight biomass composition of diets was 93.3% euphausiids, 2.6% unidentified crustacea, 1.5% *Neocalanus plumchrus* (a copepod), 1.1% each of *Nucella* gastropods and unidentified gammaridean amphipods, 0.3% unidentified gastropods, and 0.2% unidentified fish. Only 11% of the euphausiid material could be identified to species; *Thysanoessa inermis* formed 70% and *T. spinifera* 30% of this material.

Diet of winter birds was again dominated by euphausiids (99.8% of observed wet weight). Stomachs also contained small amounts of the copepods *Calanus glacialis, Neocalanus plumchrus,* and *Candacia columbiae* (0.2%) and traces of fish (<0.1%). Only 24% of the euphausiid material was identified to species; *T. inermis* formed 92%, *T. longipes* 7%, and *T. spinifera* 1% of this material.

Table 10. Age and sex compositions and collection locations of Whiskered Auklets collected for food habits studies, 1986 and 1987, Unimak Pass area, Alaska.

Cruise	Age/Sex*	Station	Date(s) Collected
Fall	3 ADM	26.2	10 October 1986
	1 SAM	26.2	10 October 1986
	2 UNM	10.3	27 September 1986
	3 UNF	10.3	27 September 1986
Winter	2 ADM	9.5,21.3	1 March 1987, 6 March 1987
	1 SAM	21.3	6 March 1987
	2 UNM	Derbin Str.	3 March 1987
	2 ADF	9.5	1 March 1987
	1 SAF	9.5	1 March 1987
	1 UNU	9.5	1 March 1987
Spring	1 ADM	8.1	30 April 1987
	2 UNM	8.1	30 April 1987
	1 UNF	8.1	30 April 1987

* AD = adult, SA = sub adult, UN = unknown age, M = male, F = female, U = unknown sex.

In spring, euphausiids (all identified material was *T. inermis*) formed 99.3% of the diet, followed by *Neocalanus plumchrus* (0.4%) and fish (0.3%).

The euphausiid *Thysanoessa inermis* was the dominant food taxon in all three collections. The average length of measured *T. inermis* declined through the study: 13.6 mm in the fall, 12.1 mm in the winter, and 11.2 mm in the spring.

Crested Auklet

During the winter cruise, nine Crested Auklets (2 adult males, 3 subadult males, and 4 subadult females) were collected. None was collected in other seasons.

Diet of Crested Auklets was mainly euphausiids (99.9%) with traces of the amphipod *Hyperia galba* (0.1%) and *Metridia pacifica* (<0.1%). Fourteen percent of the euphausiid material was identified to species; *Thysanoessa inermis* formed 80%, *T. spinifera* formed 12%, and *T. longipes* formed 8%. Mean lengths of *T. inermis* ranged from 9.5 to 14.8 mm in eight stomachs.

DISCUSSION

Seasonal Abundance

Most species recorded during this study exhibited rather substantial seasonal variations in abundance. Most of this was expected based on findings of other studies and on knowledge about the biology of the study species. Perhaps the only key species that could be considered to be resident in relatively constant levels of abundance was the Whiskered Auklet. Although this species is little studied, and thus details of its biology poorly understood, existing information suggested that it wintered near its breeding grounds. Seasonal changes in its abundance would thus be largely due to reproductive output and mortality, rather than to seasonal movement or migration.

Some comparisons between the present study and the nearby North Aleutian Shelf studies (Troy and Johnson 1987) with respect to seasonal abundances of Crested Auklets and Short-tailed Shearwaters are of interest. These two species seasonally dominated the avifauna in both areas.

Both studies reported a large wintering aggregation of Crested Auklets on the northwest side of Unimak Island. The Unimak Pass study found that substantial numbers of Crested Auklets also occurred in the tidally mixed waters of the Krenitzin Islands (Fig. 9), and that Akutan Pass was another, though secondary, center of abundance.

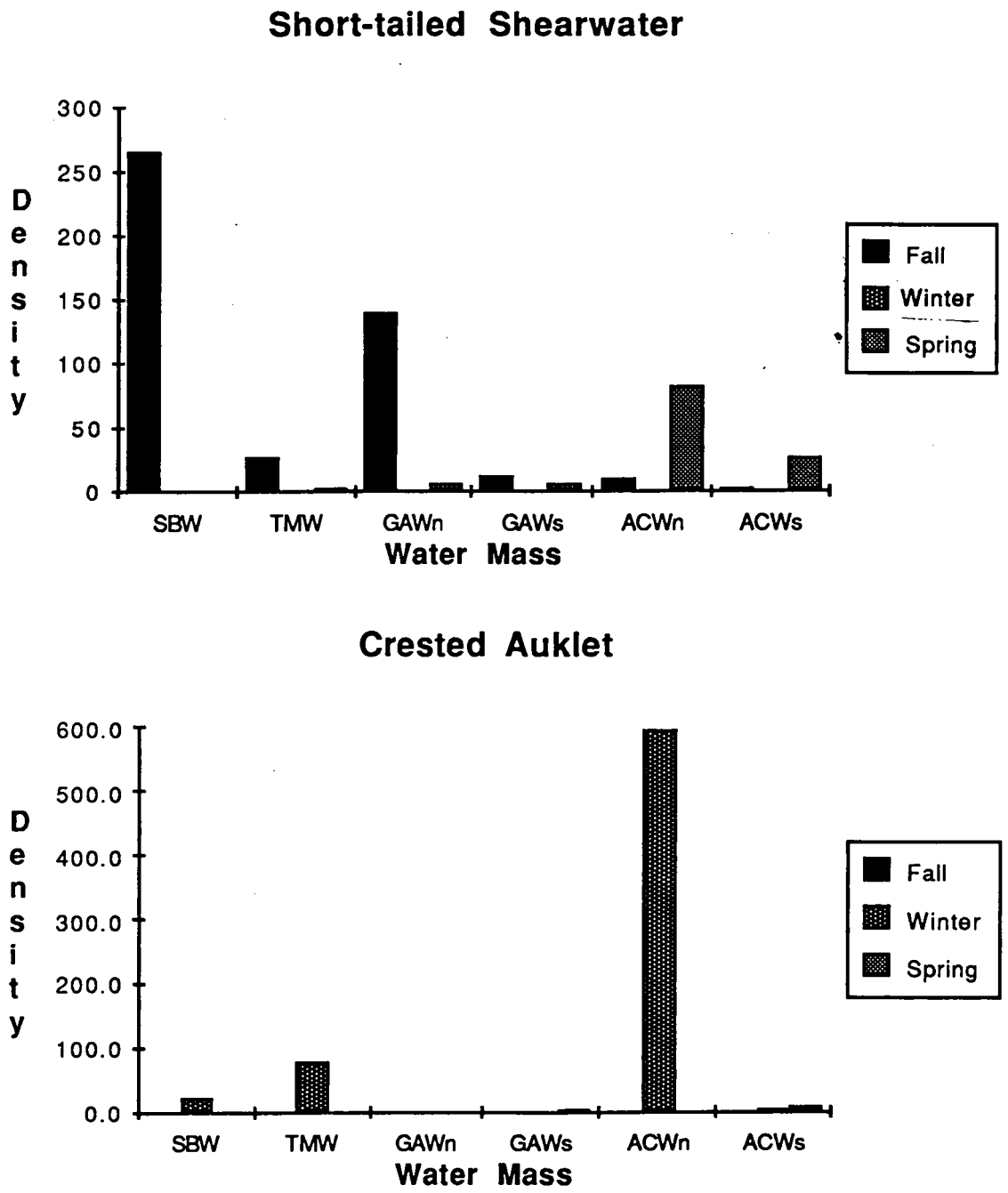


Figure 9. Average densities of Short-tailed Shearwater and Crested Auklets by water mass during fall, 1986, and winter and spring, 1987, in the Unimak Pass area, Alaska. Density estimates are based on results of ship-based surveys. Water masses are as follows: SBW=Shelf Break Water; TMW=Tidally Mixed Water; GAWn=Gulf of Alaska Water northern (Bering Sea) portion; GAWs=Gulf of Alaska Water south; ACWn=Alaska Coastal Water north (Bering Sea); and ACWs= Alaska Coastal Water south.

Short-tailed Shearwaters, virtually absent from the North Aleutian Shelf during fall, reached their peak abundance in the Unimak Pass study area at this time. This difference between the two areas seems attributable to differences in water masses present. As this study's results of densities by water mass show (Fig. 9), few shearwaters were present in fall in the Unimak Pass area in the Alaska Coastal Water; this was the only water mass sampled by the North Aleutian Shelf study. In spring, Short-tailed Shearwaters in the Unimak Pass area were almost restricted to the Alaska Coastal Water. It was during spring, a few weeks later than the timing of the Unimak Pass spring cruise, that shearwater abundance soared in the North Aleutian Shelf, supporting the idea that water mass distributions affected relative abundances between the two areas.

Spatial Distribution

Fall. The distributional maps for fall (Fig. 4) reveal some important patterns at both coarse and fine scales. On a broad scale it is evident that relatively few marine birds were present in the Gulf of Alaska away from land. However, many birds must use this region at some times, or even regularly, during the fall. The incredible number of shearwaters present to the north presumably pass through this area in fall during their southward migration, although it is possible they exit to the west (e.g., Samalga Pass). The Tufted Puffins breeding in the Krenitzin Islands must also make at least temporary use of the Gulf of Alaska. During our surveys we regularly encountered fledged puffins swimming south away from the Krenitzin Islands, and molting puffins, presumably subadult birds, were also found, albeit in low numbers, in the deepest part of the study area. It appears that puffins rapidly transit this area for regions beyond the study area. This same passage must be made on a more regular basis by the hundreds of thousands of nesting Leach's Storm-Petrels in the study area; this species was rarely recorded on transects yet it apparently transits the Gulf of Alaska portion of the study area between each visit to the nest to forage in the deep waters to the south.

The highest densities of birds were found in the Bering Sea and in the Krenitzin Islands. In this area most birds were found to the west of Unimak Pass; i.e., outside of the influence of the Alaska Coastal Current.

Perhaps the most important finding was a local concentration area involving many species located north of Akun Island in the northwestern portion of Unimak Pass. This area harbored spectacular concentrations of shearwaters, puffins, phalaropes and other birds. This region corresponds to an area of presumed upwelling, being an isolated location having salinities similar to the Shelf Break Water rather than the surrounding Gulf of Alaska

Water. It was in this area that we also had our highest catches of zooplankton (primarily euphausiids) in surface tows.

Winter. During the winter cruise, the broad-scale distributions of most marine birds revealed both a contraction and shift relative to the fall season. Most birds had vacated the deeper areas and more were concentrated near land. The passes and straits of the Krenitzin Islands and Unimak Pass thus had large numbers of birds. The change in distribution appeared as an expansion eastward such that large concentrations, especially of Crested Auklets, were now present in the Alaska Coastal Water north of Unimak Island. Murres were numerous but, as was found in the NAS studies, they were concentrated west of the Crested Auklets. In this study we found that their abundance extended west from Cape Sarichef through Avatanak Strait, at least to Akun Strait.

On a more local scale, major concentrations of birds, again mostly auklets, were found in Akutan Pass (Crested and Whiskered auklets) and Derbin Strait (Whiskered Auklets) within the Krenitzin Islands area. Sampling in the passes and straits of the Krenitzin Islands revealed high (though variable) abundances of invertebrate prey.

The Slime Bank area north of Unimak Island where the Crested Auklets were aggregated was found to have major concentrations of euphausiids within foraging range of the auklets. The observation that murre concentrations were west of the auklets (as noted in the NAS studies) may be due to the greater depth range of murres. Both groups were feeding on euphausiids as indicated by dietary analyses.

Spring. During spring there were fewer birds present than during the prior cruises and these were more dispersed. The net result was that concentrations of birds were much less noticeable than during the other cruises.

The importance of passes was perhaps most noticeable at this time of year. All the largest aggregations were present in or, more usually, just off passes. These included Short-tailed Shearwater migrants through Unimak and Ugamak passes, murres south of Akutan Pass, and auklets off most passes of the Krenitzin Islands. The auklets demonstrated an interesting distributional pattern—Crested Auklets occurred south of the Krenitzins and Whiskered Auklets were north of and within the Krenitzins.

The zooplankton distribution data indicate that in spring the major concentrations of euphausiids still occurred along the north side of Unimak Island. This was not where the birds were but, based on existing knowledge, where the shearwaters were heading. The relatively high abundance of birds near passes but the low zooplankton catches there may indicate that tidal action resulted in regular but ephemeral concentrations of prey that the birds

were able to exploit but that we missed. Zooplankton availability may increase during periods of high currents when we were unable to sample within or near the passes.

Associations with Water Masses

All the species examined exhibited rather striking associations with particular water masses or with subsets of water masses, as indicated above by the seasonal influence of water masses on Crested Auklet and Short-tailed Shearwater. Examples from some of the other key species are summarized here.

Two species—Fork-tailed Storm-Petrel and Black-legged Kittiwake—were characteristic of Shelf Break Water (Fig. 10). Both these species were rare except during fall. In the North Aleutian Shelf area, Black-legged Kittiwakes were most frequent during the nesting season near colonies (Troy and Johnson 1987). In the case of the Unimak Pass area, we had neither a summer survey nor the presence of colonies of these species, so predictions would be difficult to make about their summer distribution.

Fulmars showed a fair bit of variability in water mass use, with some seasonal trends apparent (Fig. 11). They peaked in the Shelf Break Water during fall and in the Alaska Coastal Water (north) during winter and spring. In both spring and fall they were frequent in the Gulf of Alaska Water in the north, but not in the south. Tidally Mixed Waters and the Alaska Coastal Water (south) were also rarely used. Their distribution may be partly explainable by the distribution of fishing fleets, as this species is prone to scavenging for offal. However, at all times they tended to stay in the Bering Sea, even though fishing vessels occupied the Gulf of Alaska side of the study as well as the Bering side.

Glaucous-winged Gulls provided a much simpler picture (Fig. 11). Seasonal variability appeared minimal. The highest densities were located in the Alaska Coastal Water (north), but all water masses were used. Glaucous-winged Gulls are the most consistently encountered seabird of the Unimak Pass and North Aleutian Shelf areas.

Somewhat surprising was the distribution of seaducks (Fig. 12). Seaducks were identified as a key study group because it was suspected that major wintering concentrations might be found in the Krenitzin Islands. As will be confirmed later (Chapter 7: COASTAL MARINE BIRDS AND MAMMALS, this volume) there were indeed seaducks present but no major concentrations. Populations along the North Aleutian Shelf (Troy and Johnson 1987) were substantially larger. Similarly, our census data revealed higher seaduck densities in the northern Alaska Coastal Water (i.e., along Unimak Island adjacent to the North Aleutian Shelf) than in the Tidally Mixed Water of the Krenitzin Islands. The association with the ACW may be

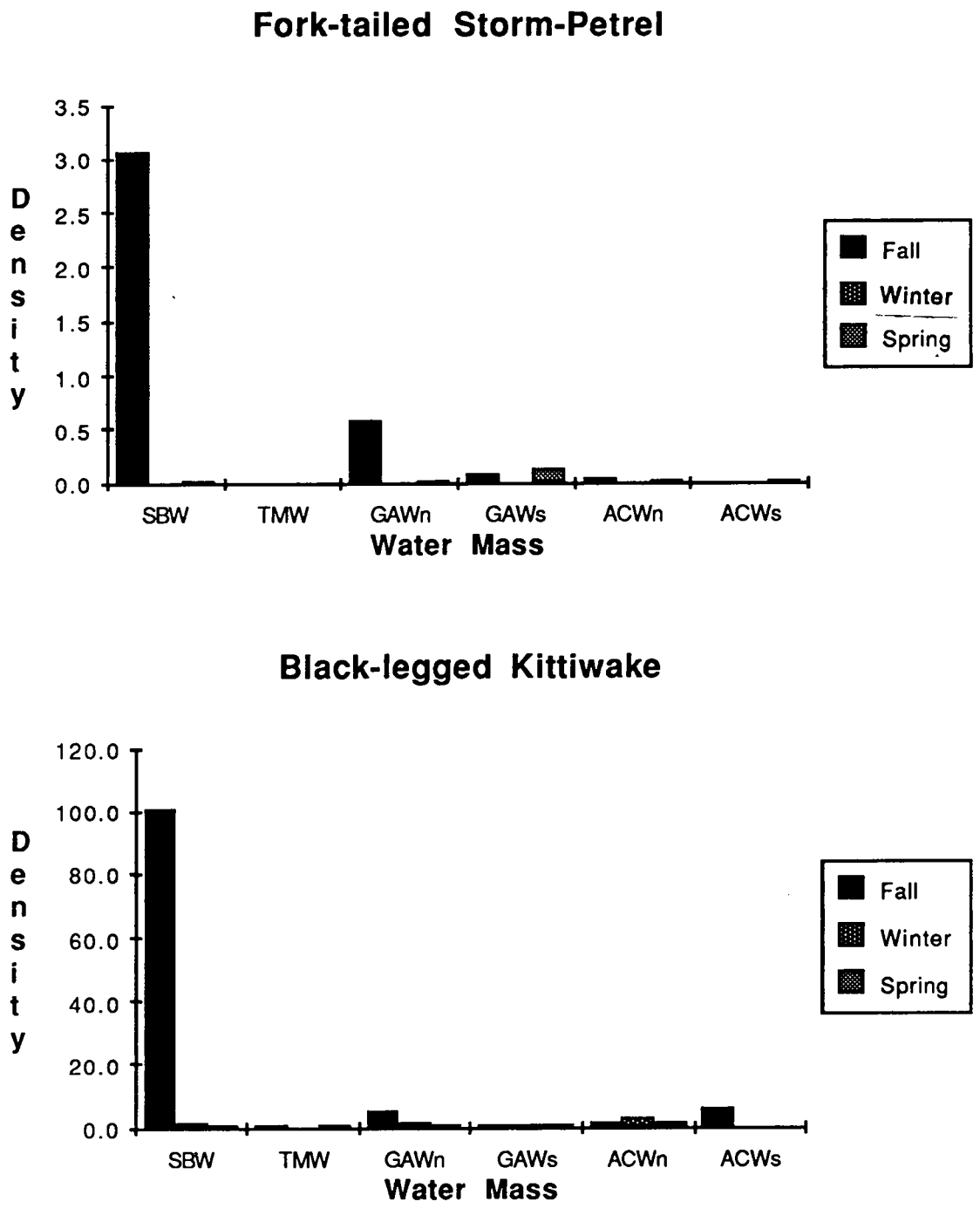
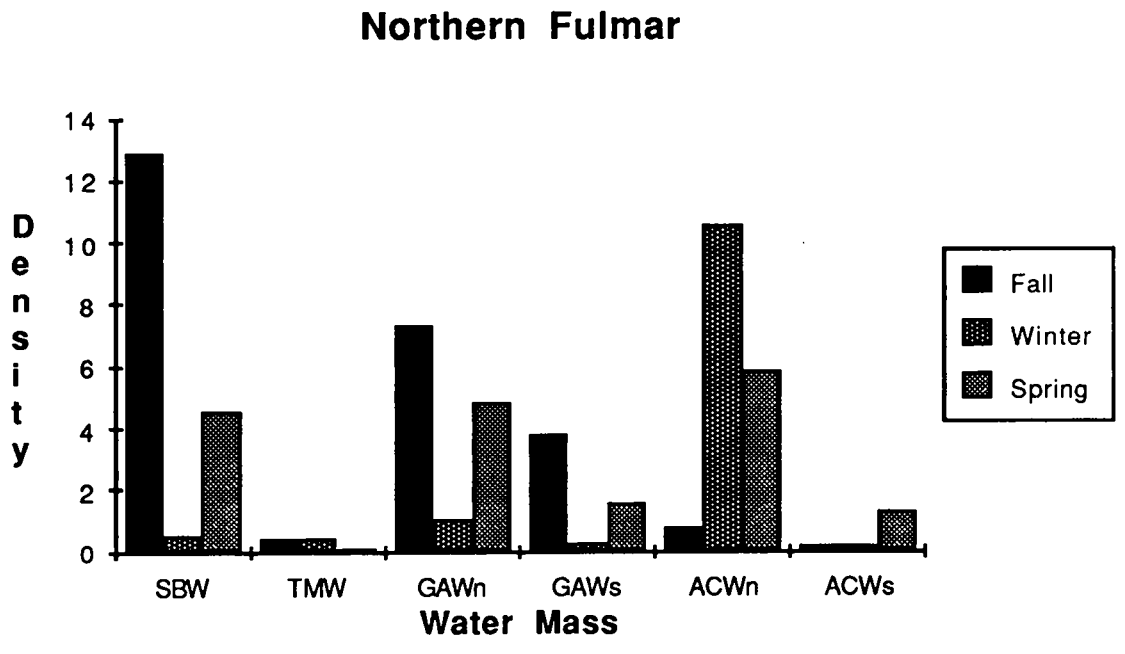


Figure 10. Average densities of Fork-tailed Storm-Petrel and Black-legged Kittiwake by water mass during fall, 1986, and winter and spring, 1987, in the Unimak Pass area, Alaska. Density estimates are based on results of ship-based surveys. Water masses are as follows: SBW=Shelf Break Water; TMW=Tidally Mixed Water; GAWn=Gulf of Alaska Water northern (Bering Sea) portion; GAWs=Gulf of Alaska Water south; ACWn=Alaska Coastal Water north (Bering Sea); and ACWs= Alaska Coastal Water south.



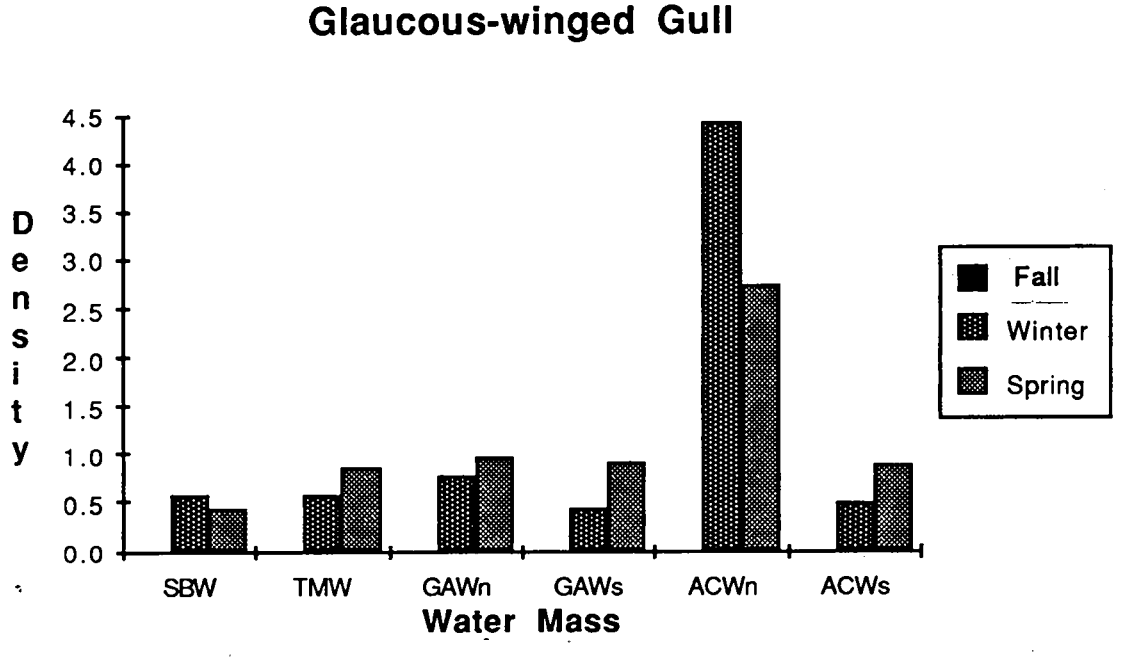


Figure 11. Average densities of Northern Fulmar and Glaucous-winged Gull by water mass during fall, 1986, and winter and spring, 1987, in the Unimak Pass area, Alaska. Density estimates are based on results of ship-based surveys. Water masses are as follows: SBW=Shelf Break Water; TMW=Tidally Mixed Water; GAWn=Gulf of Alaska Water northern (Bering Sea) portion; GAWs=Gulf of Alaska Water south; ACWn=Alaska Coastal Water north (Bering Sea); and ACWs=Alaska Coastal Water south.

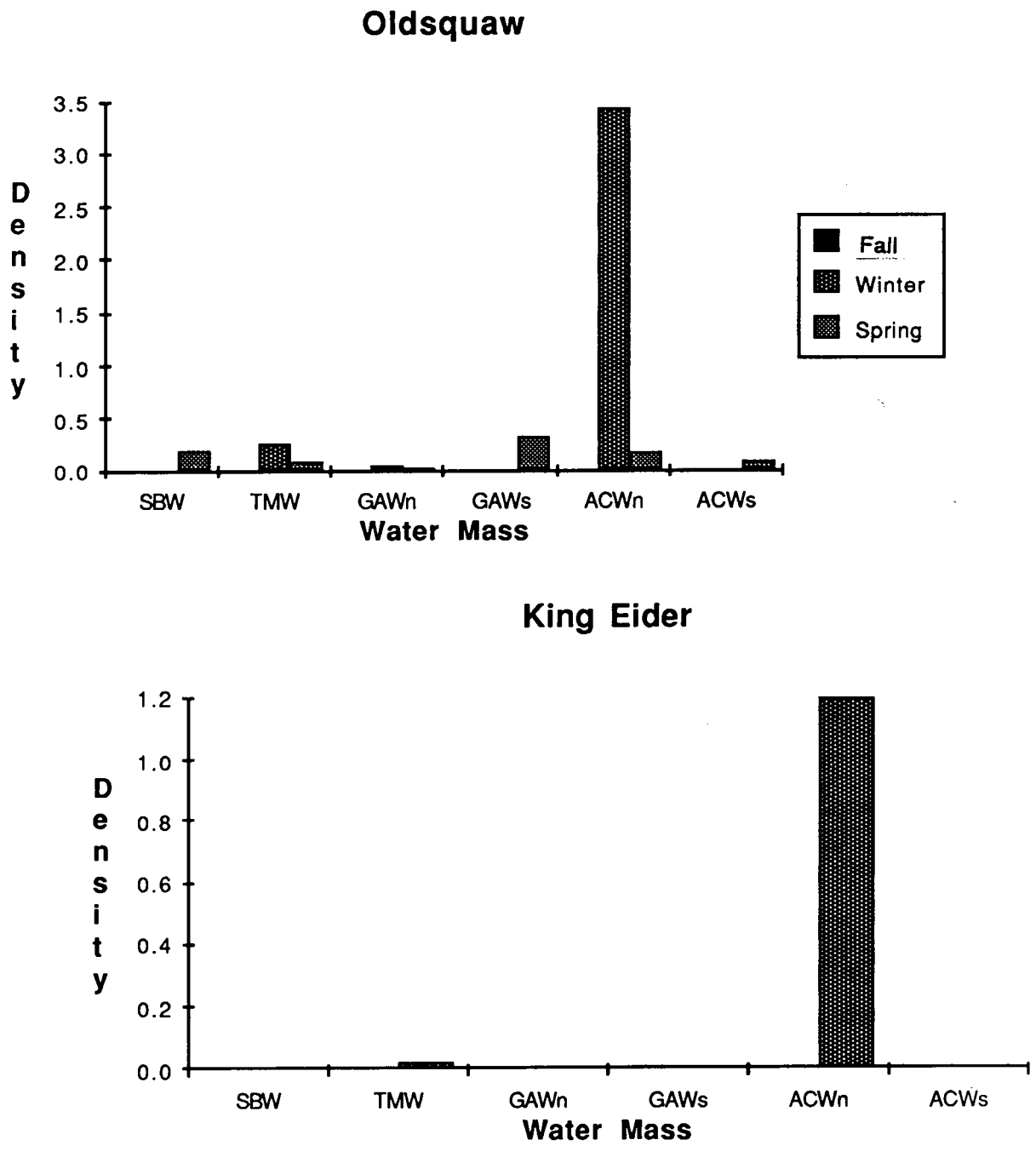


Figure 12. Average densities of Oldsquaw and King Eider by water mass during fall, 1986, and winter and spring, 1987, in the Unimak Pass area, Alaska. Density estimates are based on results of ship-based surveys. Water masses are as follows: SBW=Shelf Break Water; TMW=Tidally Mixed Water; GAWn=Gulf of Alaska Water northern (Bering Sea) portion; GAWs=Gulf of Alaska Water south; ACWn=Alaska Coastal Water north (Bering Sea); and ACWs= Alaska Coastal Water south.

partly depth-related, because the ACWn occupies most of the shallow water (≤ 50 m) sampled, and the seaducks are all bottom feeders and cannot forage in the deeper areas. However, Nyström and Pehrsson (1988) suggested that salinity also is an important habitat barrier for wintering diving ducks, and the ACW in general is the least saline water mass in the study area.

The Tidally Mixed Water had the most distinctive avifauna. The species most characteristic of this habitat were Whiskered Auklet and Tufted Puffin (Fig. 13). Whiskered Auklets were always present and always predominantly within this water mass. They ventured into the Gulf of Alaska Water both north and south of the Krenitzin Islands but in relatively low numbers. The puffins, in contrast, were present only during fall. They are known to nest abundantly in the Krenitzin Islands and, during nesting, to do most of their foraging near the colonies; during winter, they disperse. The fall cruise occurred while most birds were still feeding nestlings.

Several studies have documented concentrations of seabirds associated with oceanographic features. Some parallels between our results and those of other investigators are apparent. For example, Brown (1988) found that wintering Dovekies (*Alle alle*), the only auklet common in the Atlantic, were attracted to boundary fronts and dense swarms of zooplankton near the shelf break off maritime Canada. The huge auklet concentrations in the Unimak Pass area seemed associated with zooplankton swarms (though not with fronts *per se*). Both Brown's and our studies did find that auklets were associated with dense swarms of zooplankton.

Food Habits

A main finding of the dietary analyses was the importance of *Thysanoessa* euphausiids, especially *T. inermis,* to some birds. *T. inermis* has the center of its distribution in Alaskan waters in the Pacific Ocean (Brinton 1962), and in the Bering Sea is typically an oceanic species, sometimes common over shelf margins (Cooney 1979). In this study, *T. inermis* was found to be important to Short-tailed Shearwaters and Whiskered Auklets during the fall; to Common Murres, Whiskered Auklets and Crested Auklets in the winter; and to Whiskered Auklets in the spring. The importance of euphausiids in the diet of Short-tailed Shearwaters was demonstrated earlier by Krasnow and Sanger (1982) and Sanger (1983).

Previous to this study, the diet of Whiskered Auklets was virtually unknown. Byrd and Gibson (1980) and others have noted that these birds are found in close association with tide rips and other surface water discontinuities in the Aleutians. This study found that the birds were taking *Thysanoessa* euphausiids almost exclusively, regardless of the season. Copepods, including *Calanus glacialis, Neocalanus plumchrus,* and *Candacia columbiae* were taken in only trace amounts.

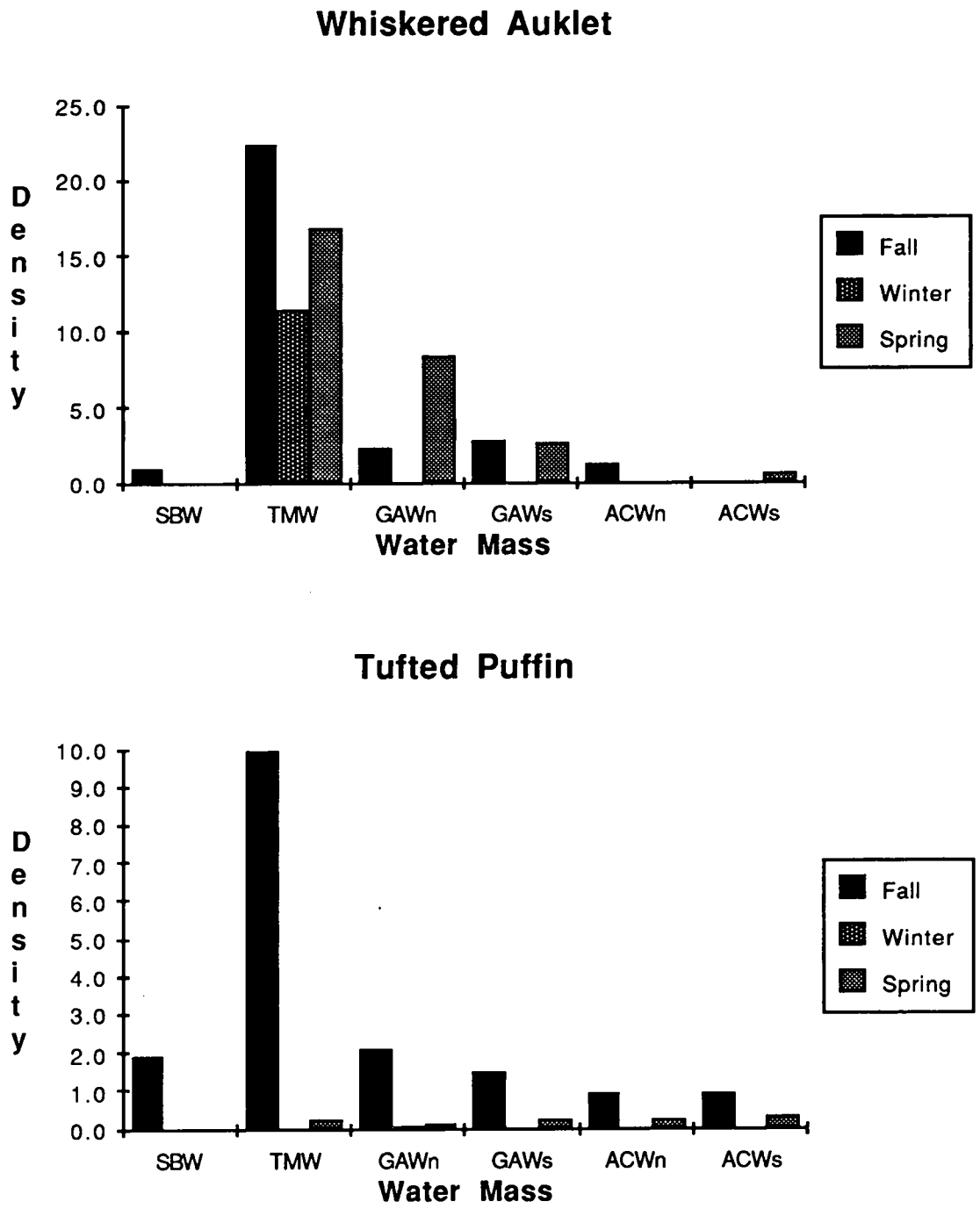


Figure 13. Average densities of Whiskered Auklet and Tufted Puffin by water mass during fall, 1986, and winter and spring, 1987, in the Unimak Pass area, Alaska. Density estimates are based on results of ship-based surveys. Water masses are as follows: SBW=Shelf Break Water; TMW=Tidally Mixed Water; GAWn=Gulf of Alaska Water northern (Bering Sea) portion; GAWs=Gulf of Alaska Water south; ACWn=Alaska Coastal Water north (Bering Sea); and ACWs= Alaska Coastal Water south.

Crested Auklets are well known to specialize on euphausiids during the breeding season (Bedard 1969, Hunt et al. 1981a, Bradstreet 1985). Bedard (1969) found that Crested Auklets took other invertebrate types early in the breeding season, and Krasnow and Sanger (1982) found the mysid *Acanthomysis* to be dominant in stomachs of two birds collected in January near Kodiak Island. Sanger (1983) found that amphipods and copepods, in addition to mysids, were important food items. In this study, Crested Auklet diet was composed almost solely of euphausiids, with *Thysanoessa inermis* predominating; only traces of amphipods (*Hyperia*) and copepods (*Metridia*) were found.

In this study, the stomachs of three Common Murres collected in winter contained *Thysanoessa* euphausiids. Elsewhere, winter diet is largely fish (Tuck 1960, Baltz and Morejohn 1977, Blake et al. 1985), though Sanger (1987) found mysids and shrimp to be important in Kachemak Bay, Alaska, in winter. Common Murres are also known to feed on euphausiids during the summer (e.g. Hunt et al. 1981a, Schneider and Hunt 1982, Bradstreet 1985), though the diet then is usually dominated by fish.

In spring, the stomach contents of seven murres collected in this study were mostly *Ammodytes*, although euphausiids occurred in more stomachs than did fish. Blake et al. (1985) reported seasonal changes in the diets of Common Murres collected in the North Sea, but the changes noted were mainly among species of fish. In their samples, invertebrate remains (polychaete jaws) occurred mainly in winter.

Of the five species collected, only Tufted Puffins did not use euphausiids to a significant degree. The puffins collected depended largely on small *Gonatus* squid during the winter and *Ammodytes* fish during the spring. Other observations indicated that small pollock were important, at least as food for nestlings, during the fall. Wehle (1982) found that adult and subadult Tufted Puffins collected in the western Aleutians during the summer relied primarily on squid—squid occurred in 85% of 106 stomachs and fish occurred in 26%.

RECOMMENDED FURTHER RESEARCH

Temporally, our surveys occurred during three of the four seasons. Missing was sampling during summer, a period of intensive bird use of the adjacent North Aleutian Shelf and probably the Unimak Pass area. Summer also corresponds to the breeding season, when large numbers of seabirds are known to use the Krenitzin Islands.

Spatially, our coverage was rather complete and, in conjunction with the North Aleutain Shelf studies, provides good coverage of much of the

region. Missing in comparable coverage are the region to the southeast (south side of the Alaska Peninsula) and to the west. Although there are known areas of importance along the south side of the Alaska Peninsula, those areas immediately adjacent to our study area did not appear to support large numbers of birds during the seasons surveyed. The southern portion of the Alaska Coastal Current was the most consistently poor area for birds. Thus we would not recommend research in this area as a priority. In contrast, the observation of intensive bird use of areas off passes, especially on the north side of the Aleutian Islands, and the observations of major nutrient influxes from the west into the northern parts of the Unimak Pass area (see Chapter 2: PHYSICAL PROCESSES AND HYDROGRAPHY, this volume), suggest that further research in the waters north and west of Unimak Island is high priority.

The main areas of research that would best complement what we have done thus far are:

1) To conduct an additional cruise similar to the ones described in this report during the summer season, perhaps late June and early-July, and

2). To conduct a study similar to the Unimak Pass investigation that extends coverage as far west as Samalga Pass in the Aleutian chain.

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